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EVERYTHING FOR ELECTRONICS

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Model TrainSaver

Easiest Internet Protocol

Choosing a Heatsink

Understanding Digital Logic ICs

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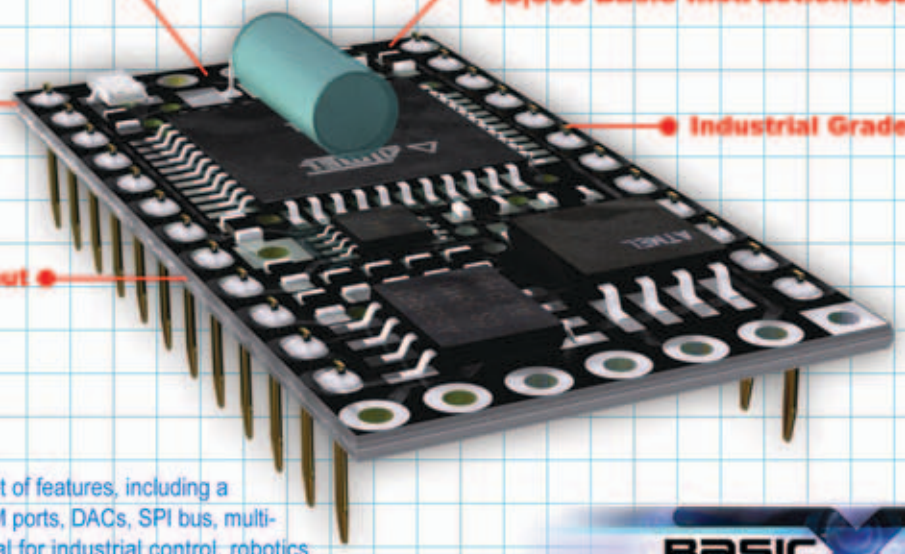

FEATURES: The BX24-P has a vast set of features, including a full IEEE floating point math library, COM ports, DACs, SPI bus, multi-tasking and networking, making it ideal for industrial control, robotics, automated testing equipment and home automation. BX24-P is able to monitor and control all your switches, timers, motors, sensors, relays, and more. Measuring just 1.25" X .75", OEMs can easily see the value of this little powerhouse.

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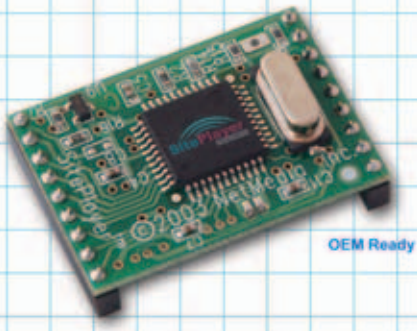
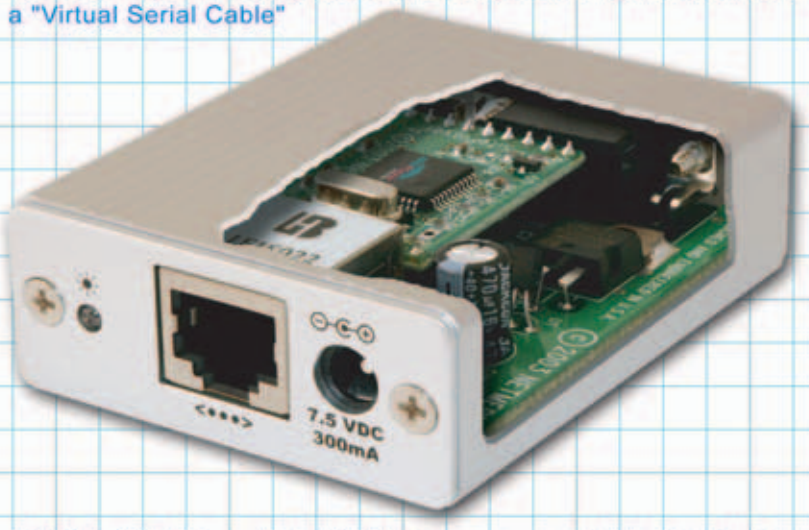


OEM Ready



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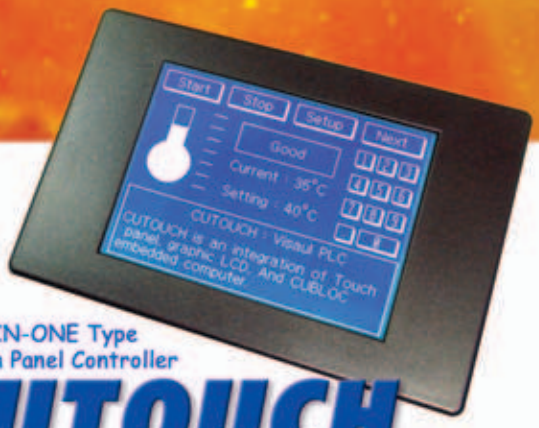
FLASH 80KB, 16 I/O

CB280
FLASH 80KB, 49 I/O

CB290
FLASH 80KB, 91 I/O



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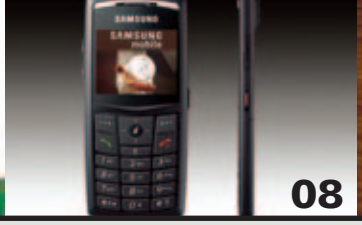

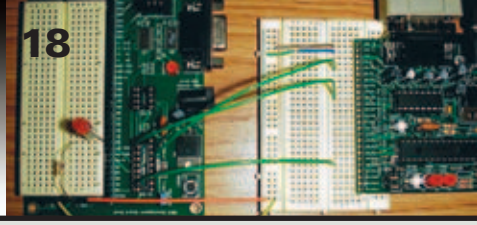

NUTS AND VOLTS

JULY 2006

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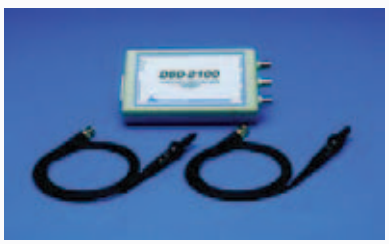
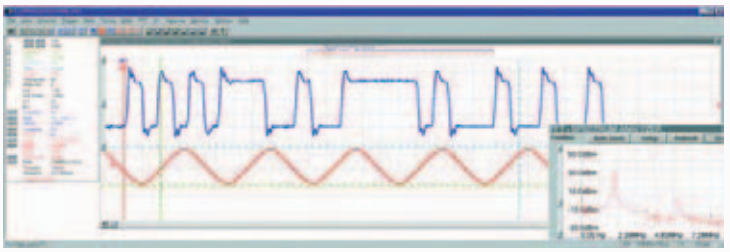
Digital Oscilloscopes





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READER FEEDBACK

NUTS AND VOLTS
EVERYTHING FOR ELECTRONICS

CONSTANT SOURCE OF IRRITATION?

I am writing about the Constant Current Sources article in the May issue. I assume you will get many letters about this one. I have seldom seen such messed up articles. When I showed it to my wife, the first thing she did was check to see if it was an April issue!

All the figures show voltmeters with high and low leads — what is the significance of these? The text for Figure 4 belongs with Figure 5. I think the text for Figure 5 belongs to Figure 6. The circuitry in Figure 6 has nothing to do with potentiometers, and there is no figure for them. The scope setup sounds complicated.

In the part about measuring capacitors, we find, "... the measured time for the voltage across the capacitor to rise from zero to its rated value is proportional to the capacitance." The truth is that the time for a rise to any particular voltage is proportional to the capacitance. And the particular CCS used might not have a maximum voltage to match the rated voltage of the capacitor. To do the test, I would use a stopwatch and measure the time for the voltage to reach some convenient value. Before the test, one is told to short-circuit the capacitor with a 1K resistor to ground. What ground? Just short-circuit it. And it says the time can vary from 0 to 60 seconds. But there is no such limit. And in the example using a current of 1 mA, the math actually uses a current of 10 mA, and if the correct 1 mA were used, the time would be 100 seconds, well over the above limit of 60.

One final comment — the article says digital storage oscilloscopes are virtually the only scopes manufactured today. That is news to me, as I seldom see advertisements for them, but ads for the ordinary scopes are common.

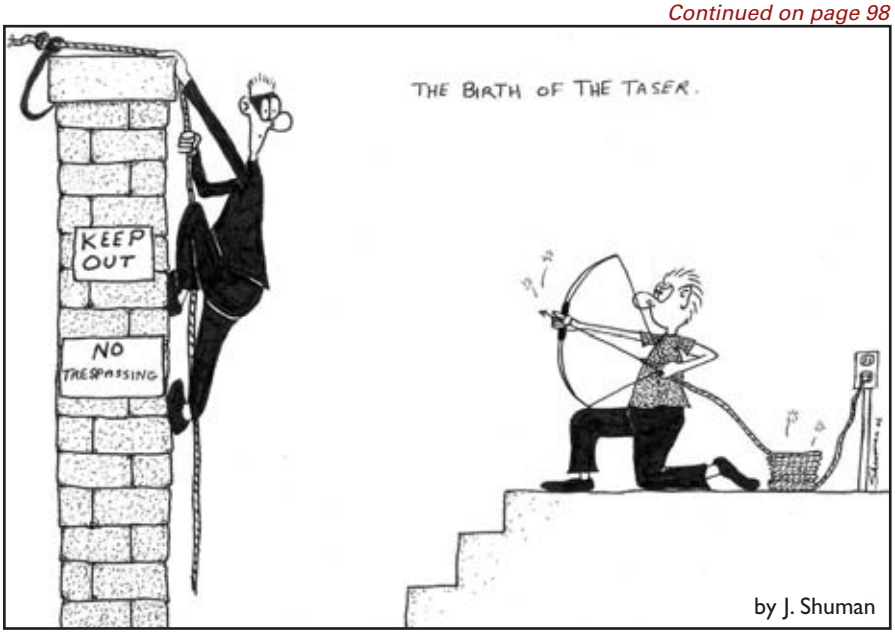
Kenneth E. Stone
Cherryvale, KS

Writer Response:

In response to this letter that was critical of the May issue article on constant current sources, thanks for your reply. Yes, there was a piece of artwork that was inadvertently omitted and this had a "displacement" effect and adversely impacted subsequent pieces of line art, as well as text, to some degree, for which I apologize.

As for the charging of a capacitor, the point that was to be made was that a capacitor in an RC circuit charges logarithmically and after 5 tau (ô) or time

Continued on page 98



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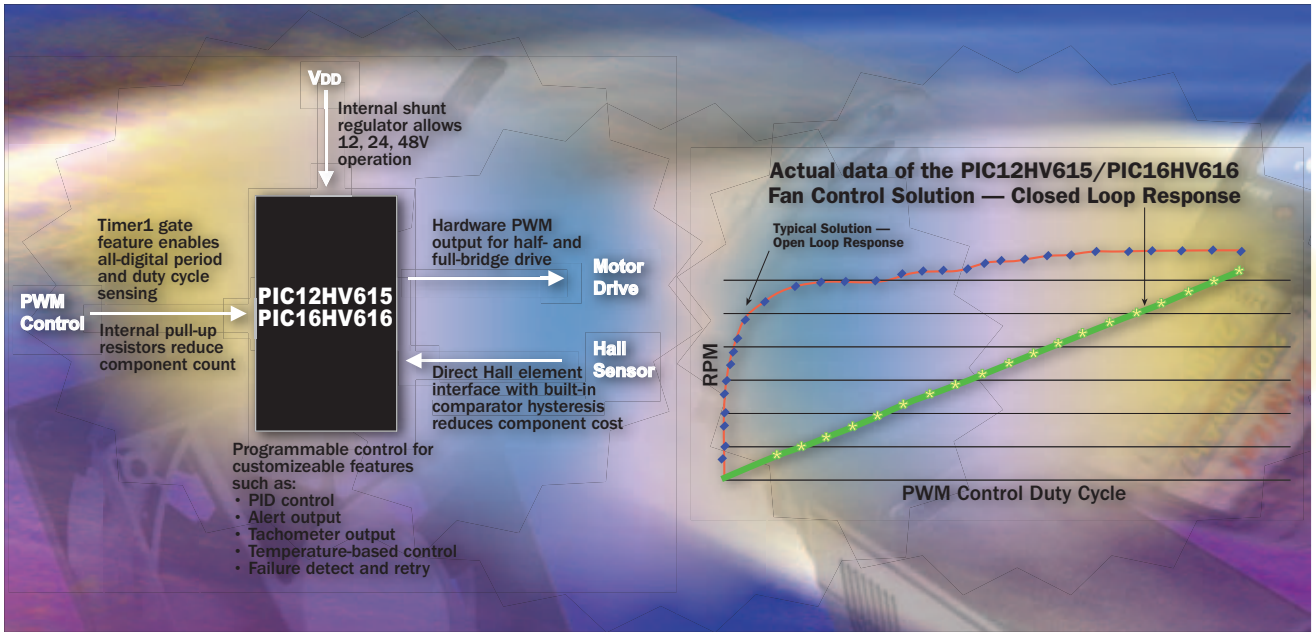

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PIC16HV616	Yes	3.5 KB/2 Kw	8	2	Full bridge	8 MHz

* Capture, Compare, PWM

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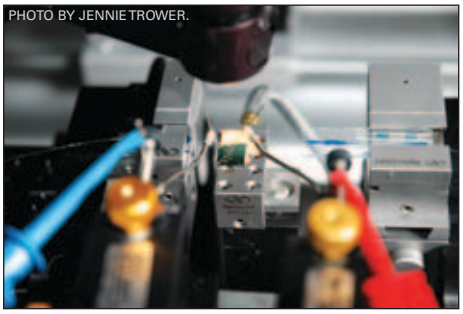
TECH KNOWLEDGEY 2006

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

SILICON DEVICE MODULATES LIGHT



■ Two voltage probes contacting the surface of the green silicon chip with the photonic crystals where the laser light's transmission is slowed to modulate it.

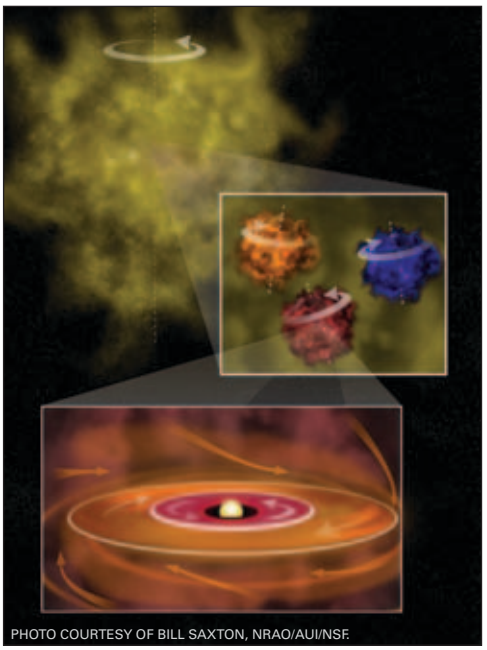
For many years, researchers have been trying to figure out how to use light in silicon chips because of its ability to move thousands of times faster than electrons in solid materials. It now appears that an electrical engineer at the University of Texas at Austin (**www.utexas.edu**), backed up with the sponsorship of the Air Force Research Lab (**www.afrl.af.mil**), has figured out how to do it.

Professor Ray Chen and some grad students have created a chip made of silicon "photonic crystals" whose complex internal structure can reduce the speed of laser light traveling through the chip such that a small electric current can alter, or modulate, the pattern of light transmission. The result is a chip that causes the light to blink on and off at different rates, or at least to change in intensity, and the blinks could be used to encode and transmit data.

In computers, the light-modulating chips would primarily serve to send information between a computer's microprocessors and its memory. According to Chen, more than 50 percent of a Pentium 4's power is consumed by this interconnection, and doing it optically could reduce this considerably. The device can produce modulation in a distance of only 80 micrometers, which is about a tenth of the distance required by traditional silicon optical modulators.

Once Chen's devices are combined with lasers on a silicon platform, the chips could become a mainstay of consumer electronic devices, telecommunication systems, biosensors, and other devices, allowing higher speeds and lower power consumption.

RADIO TELESCOPE SEES STRANGE SOLAR SYSTEM FORMATION



■ Building a counter-rotating protoplanetary disk.

Using the Very Large Array radio telescope operated at the National Science Foundation's National Radio Astronomy Observatory (**www.nrao.edu**), astronomers have discovered a disk of material encircling a still-forming star within our galaxy. The interesting thing is that the inner part of the disk is rotating in the opposite direction from the outer part. This implies that when the disk — which is basically a giant cloud of gas and dust — collapses and forms planets, some of the planets will orbit in opposite directions.

According to Anthony Remijan, of the NRAO, "This is the first time anyone has seen anything like this, and it means that the process of forming planets from such disks is more complex than we previously expected."

The system was discovered by Remijan and a colleague, Jan M. Hollis of NASA's Goddard Space Flight Center (**www.gsfc.nasa.gov**). The assumption is that this system contains material from two different clouds instead of a single one.

At the top of the illustration, a huge star-forming region is rotating in the direction of the arrow. This region can give birth to multiple star systems. The center image shows the inside of the star-forming region, which shows three protostars forming as the region collapses. The process is chaotic enough to cause eddies, which allows newly forming stars to rotate in different directions. The bottom view shows one cloud collapsing into a disk-like structure that rotates counterclockwise in the center but siphons off material from a second, passing protostellar cloud that rotates clockwise.

If you want to pay it a personal visit, just head out toward the constellation Ophiuchus. The thing is about 500 light-years from Earth, though, so take a change of underwear.

COMPUTERS AND NETWORKING

NEW INTEL PROCESSORS ON THE WAY

Formerly code-named Conroe and Merom, Intel (**www.intel.com**) has unified the brand name and introduced

■ Intel's Core™ 2 Duo processors are slated for arrival in the third quarter of this year.
PHOTO COURTESY OF INTEL CORP.

the Core™ 2 Duo processors for desktop and notebooks PCs, respectively. The chips are based on a newly designed microarchitecture and will include two processing cores per chip (hence the "Duo" addition). Intel will also call its top-end processor, aimed at gamers and other high-performance applications, the Intel® Core™ 2 Extreme processor.

According to Intel, these devices will be built on a 65-nanometer design and manufacturing process technology that shrinks a processor's circuitry and transistors, thus producing both higher performance and energy efficiency. They will include what is billed as the industry's largest integrated memory reservoir, called the Intel Advanced Smart Cache, which includes an improved design for faster performance in memory-intensive applications.

The basic idea is that having a common microarchitecture for the consumer, gaming, notebook, and business desktop market segments will make it easier for computer developers to create more efficient software applications and provide the ability to share capabilities across all categories.

17-INCH LAPTOP INTRODUCED

We may now be approaching a point at which the average lap isn't big enough to support a "laptop" computer, with 17-inch machines becoming the norm and a few even sporting 19-inch displays (although giving you the same 1680 by 1050 pixels). One of the latest machines apparently designed to make airline travel even more uncomfortable is Apple's new 17-inch version of the MacBook Pro. But at least it's still only one inch (25 mm) thick and weighs only 6.8 lbs (2.54 kg).

■ Apple's MacBook Pro is now available in a 17-inch version.
PHOTO COURTESY OF APPLE.

It features a 2.16 GHz Intel Core Duo processor and an improved architecture that is said to provide five times the performance of the PowerBook® G4, a 667 MHz front-side bus that is four times as fast as the G4, and 667 MHz DDR2 SDRAM memory (expandable to 2 GB) that is twice as fast. The suggested (and generally observed) retail price is $2799.

SPAM WAR REACHES NEW LEVEL

You may be familiar with Blue Security, Inc. (**www.bluesecurity.com**), purveyors of the Blue Frog application. Blue Frog basically enables you to place your email address in the company's "Do Not Intrude" Registry and download the Blue Frog application. Blue Frog actively fights spam by posting opt-out requests on the sites advertised by spam.

Users may report spam from any desktop email client or let Blue Frog automatically report Gmail, Hotmail, and Yahoo! spam directly from a browser. It will send up to 1,000 opt-out messages to the same advertiser, thereby making his life almost as miserable as yours.

According to the company, six out of the 10 most active spammers have stopped sending things to the "blue community" of more than 500,000 users. Unfortunately, though, some of the spammers, and in particular one identified as "PharmaMaster," have decided to up the ante. Apparently, PharmaMaster was able to block Blue Security's former IP address at the backbone routers, thus knocking out the system for users located anywhere outside of Israel.

He also somehow engineered a massive denial of service attack on sites associated with Blue, causing five hosting providers in the US and Canada, a major DNS provider, and a popular blog site to go down for several hours. In addition, a spammer somehow derived the addresses of Do Not Intrude members and bombarded them with threatening messages, which in part read, "You are receiving this email because you are a member of Blue Security. Due to the tactics used by Blue Security, you will end up receiving this message, or other nonsensical spams 20-40 times more than you would normally." As of this writing, the Blue website is up and running again but is still having a few operational problems.

On the positive side, a 20-year-old (Jeanson Ancheta, a member of the Botmaster Underground) who was prosecuted for hijacking computers, damaging computer networks, and sending waves of spam and viruses was recently sentenced to 57 months in prison, ordered to pay $15,000 in damages, and fork over $60,000 in illicit gains to the government.

In addition, a court recently ordered Sanford Wallace and his company — **Smartbot.Net** — to turn loose of $4,089,500 that it derived from a spyware scam. Apparently, the Internet will remain a dangerous place for a long time, but sometimes you win a few.

CIRCUITS AND DEVICES

SLIMMER CELL PHONE

PHOTO COURTESY OF SAMSUNG.

■ Samsung's new X820 is billed as the world's slimmest phone.

If you're tired of people asking you, "Is that a cell phone in your pocket or are you glad to see me?" then you may be interested in Samsung's X820, which is only 6.9 mm (0.27 in) thick and weighs in at a mere 66 g (2.3 oz). It offers a

INDUSTRY AND THE PROFESSION

OPENDOCUMENT STANDARD ADOPTED

The Joint Technical Committee 1 on Information Technology of the International Standards Organization/International Electrotechnical Commission (ISO/IEC) recently approved a new standard that covers the OpenDocument format as submitted by the Organization for the Advancement of Structured Information Standards (OASIS, **www.oasis-open.org**). The newly approved ISO/IEC 26300, Open Document Format for Office Applications (OpenDocument) v1.0, has been designed to be used as a default file format for office applications, with no increase in file size or loss of data integrity.

OpenDocument defines an open XML file format that will allow users to save and exchange editable office documents such as text documents (including memos, reports, and books), spreadsheets, databases, charts, and presentations, regardless of application or platform in which the files were created. This will facilitate document contents' access, search, use, integration, and development in new and innovative ways.

Reportedly, the folks at Microsoft — who have been pushing their own version (Office Open XML) — is not entirely pleased, even though it is a sponsor of OASIS. Current members of OASIS committees focusing on OpenDocument include representatives of Adobe, IBM, Intel, Novell, Oracle, and Sun Microsystems, as well as government agencies and other organizations, such as the Chanfeng Open Standards Platform Software Alliance in China, National Informatics Center of the Government of India, Netherlands Tax and Customs Administration, Royal National Institute for the Blind, and Duke University.

functional keypad and a beveled cut for a natural grip, and the case is made of fiberglass-infused plastic for strength and weight reduction. It also includes a two-megapixel camera, Bluetooth, an MP3 player, and a 176 x 220 color display.

You may have to wait a while to get one, though. It will be marketed first in Russia and later in Europe, but the company hasn't mentioned the introduction of a US version as of this writing. The best you can do in this country is the model T509, available from T-Mobile. It's a relatively plump 9.8 mm (0.39 in) thick. Details are available at **www.samsung.com**

HIGH-SPEED DATA RECORDER INTRODUCED

The new Dash 8HF from Astro-Med (**www.astro-med.com**) is a ruggedized eight-channel data recorder that was engineered specifically for capturing high-frequency data and transient signals. Ruggedized and portable to make it suitable for both field and lab use, the unit supports recording up to eight channels of isolated inputs to an internal hard drive at sample rates of up to 2 MHz with a bandwidth of 200 kHz per channel.

PHOTO COURTESY OF ASTRO-MED, INC.

■ Astro-Med's Dash 8HF is a portable data recorder for field or lab use.

The Dash 8HF includes a 250 GB internal hard drive and a DVD burner for storing and archiving data. Other features include 10/100/1000BaseT Ethernet for data upload and a USB 2.0 port for archiving data to external drives. Free Windows-based AstroVIEW X software allows data to be imported to a PC for analysis and review. Using AstroVIEW X, a user can import data to popular spreadsheet and analysis programs including Excel, FlexPro, DADiSP, and MathCAD with a simple conversion command.

The system is built into a 16 x 12.125 x 6.628 inch (approx. 41 x 31 x 17 cm) case and weighs less than 21 lbs (7.8 kg). Operating on either 120 or 240 VAC, the device includes a capacitive backup to ensure proper shutdown without data corruption if power is lost.

Primarily designed for applications in the automotive, electric utility, telecommunications, pulp and paper, metals manufacturing, steel mills, medical, and other industrial, scientific, and educational fields, it will set you back a mere $14,750. An optional high-security version is available for defense and aerospace applications. **NV**

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Q&A

WHAT'S UP:

A collection of serious questions that took time to research finally appear this month, a very cool NASA website, and more phone busy stuff.

- ✓ **DVD formats demystified.**
- ✓ **Oscilloscope probe selection.**
- ✓ **Current mirrors with experiment.**
- ✓ **LDO PIC power supplies.**

■ WITH TJ BYERS

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist.

Feel free to participate with your questions, comments, or suggestions.

You can reach me at: **TJBYERS@aol.com**

DVD FORMATS DEMYSTIFIED

Q I have a Panasonic DVD recorder (model MDR-E50) and I can't figure out how to make a recording. I mean, which recording blank to use. I called Panasonic and they said to use -DVD from TDK. But I can't figure out what that means. I've asked many sales persons, and they don't have a clue either. I will purchase a pack of 20 or more if I can be assured they are the right ones for my recorder. How do they work and how do you know which is which?

— Robert E. Smith
Fox River Grove, IL

A There are two competing DVD recording standards: DVD- and DVD+. Panasonic — along with Toshiba, Apple Computer, Hitachi, NEC, Pioneer, Samsung, and Sharp — support the DVD- format. The DVD+ format is supported by Philips, Sony, Hewlett-Packard, Dell, Ricoh, Yamaha, and others. Sometimes the two formats are interchangeable between machines, sometimes not.

Both formats have extensions: DVD-R, DVD-RW, DVD-RW DL, DVD+RW, and DVD+R, DVD+RW DL. Here are the definitions of what each means.

- R — Write once
- RW — Write/erase multiple times
- DL — Dual layer

Write once is self-explanatory. You can write to the disc one time and one time only. You can't add stuff later or erase it. It's now carved in stone. RW lets you add to, write over, or erase the data many times over (typically 1,000). Think of it as a big floppy. Dual layer means you have two layers of recording media on a single side of the disc — almost doubling the capacity from 4.7 GB to 7.95 GB. Then there are double-sided discs where you can record on both sides — like an LP record (if you can remember that far back) — further increasing the storage capacity. Currently, there is no designation for double sides, only dual layers. Still confused? Let your fingers do the walking through Table 1.

Designation	Write Multiple	Layers/Sides	Capacity (GB)	DVD Forum No.
DVD+R	N	Single/Single	4.7	DVD-5
DVD+R	N	Single/Double	8.75	DVD-10
DVD+RW	Y	Single/Single	4.7	DVD-5
DVD+RW	Y	Single/Double	8.75	DVD-10
DVD+R DL	N	Dual/Single	7.95	DVD-9
DVD+R DL	N	Dual/Double	15.9	DVD-18
DVD-R	N	Single/Single	4.7	DVD-5
DVD-R	N	Single/Double	8.75	DVD-10
DVD-RW	Y	Single/Single	4.7	DVD-5
DVD-RW	Y	Single/Double	8.75	DVD-10
DVD-R DL	N	Dual/Single	7.95	DVD-9
DVD-R DL	N	Dual/Double	15.9	DVD-18

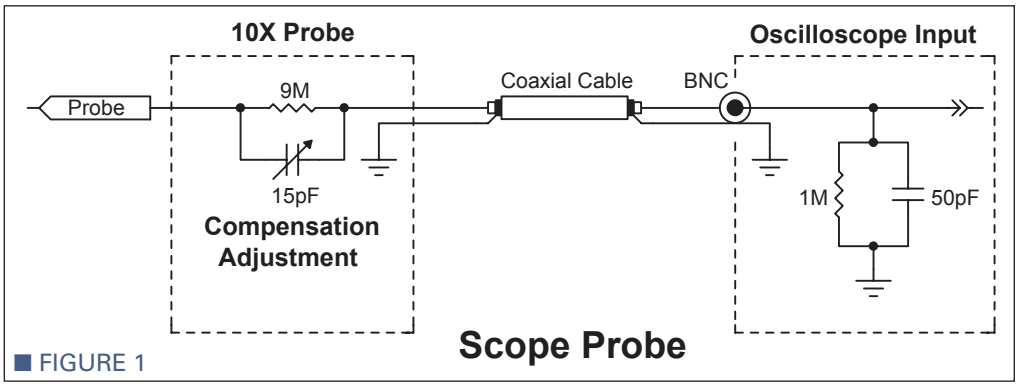
■ TABLE 1. DVD Formats.

ABOUT SCOPE PROBES

Q Recently, I was given two 25-year-old Leader LBO-15A oscilloscopes — dual-channel, 15 MHz. They both work. Having never owned a scope, it would be nice to use them. However, neither came with a probe and I don't know much about selecting one.

— Frank Lemon

A If I were you, I'd buy the 15085 TE scope probe from Marlin P. Jones & Assoc. (800-652-6733; **www.mpja.com**). It has a bandwidth of 20 MHz and sells for a low $7.95. (MPJA also sells scope probes going up to 200 MHz.) But that's just the beginning. Unless you properly compensate the probe, you will be displaying the response of the probe itself and not your circuit. Refer to Figures 1 and 2 for this discussion.



■ FIGURE 1

The typical input impedance of an oscilloscope — especially one of that era — is 1 megohm with 50 pF to 100 pF. If you put this load across a high-frequency oscillator, not only will you shift the operating frequency with the added parallel capacitance, but you risk stalling oscillation altogether. Which is why selecting a good scope probe is essential to accurate measurements.

Most probes have an attenuation factor of 10x. A 10x probe has the effect of reducing capacitance by a factor of 10. The trade-off is that it also attenuates the signal by a factor of 10. This means that 10 volts at the source becomes one volt at the scope input.

A 10x probe is made up of a 9 megohm resistor, a 15 pF trimmer capacitor, and a short length of coaxial cable (Figure 1). When added to the 1 megohm resistance of the scope, the probe tip reflects a 10 megohm load to ground. The capacitance, on the other hand, is subtractive, resulting in a reflected load capacitance of 9 pF (with the trimmer set to 11 pF).

The trimmer is used to compensate for overshoot and undershoot that is common when probing a circuit. This is done in five steps:

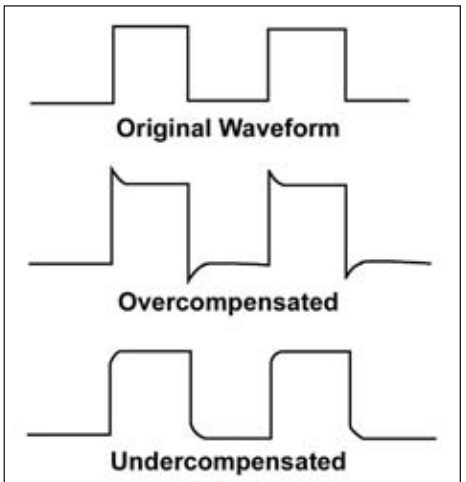
1) Connect the probe tip to the scope calibrator. (Most scopes provide a 1 kHz square wave calibrator output.)

2) Switch the channel input coupling to DC.

3) Set the volts/div switch to 1V/div (assuming the calibration voltage is five volts p-p.).

4) Set the sweep rate to 1 ms/div.

5) Adjust the trimmer until the tops and bottoms of the square wave are flat (Figure 2).



■ FIGURE 2

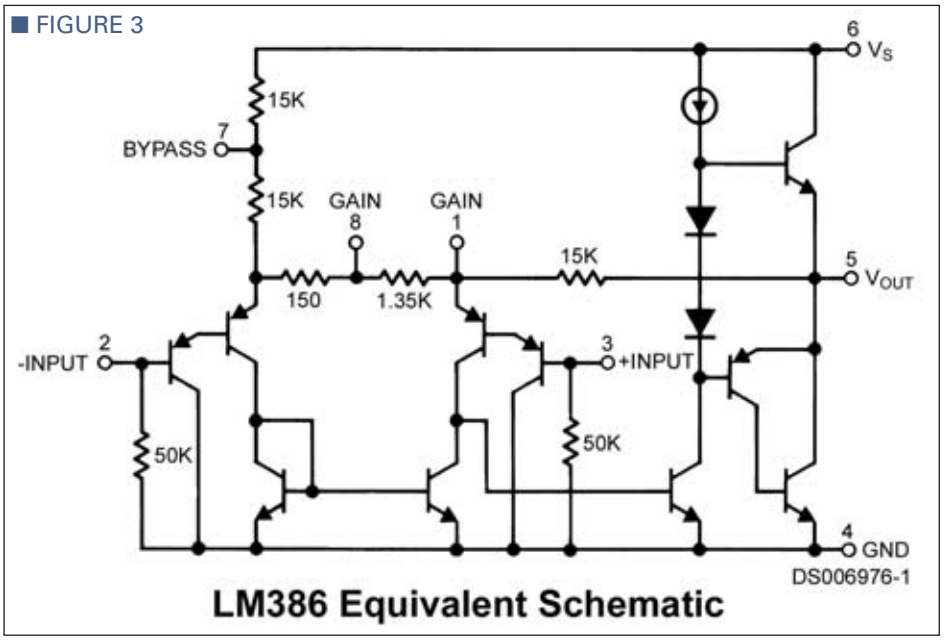
AUDIO AMP INPUT CONFUSION

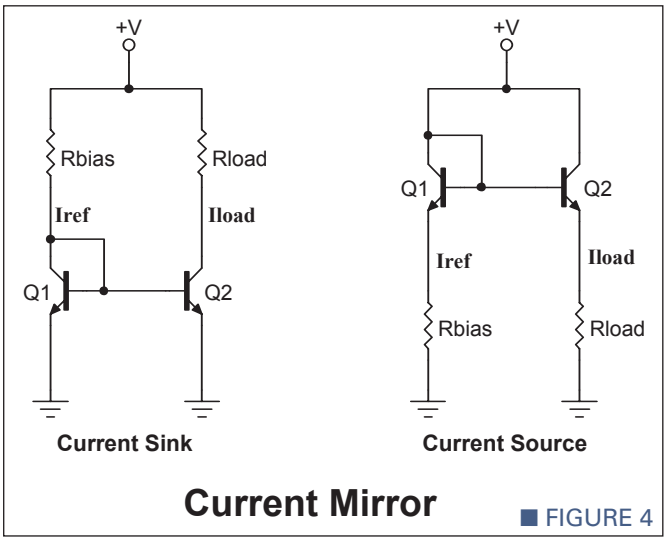
Q The October '04 issue showed the details of a 700 mW audio power amp using an LM386. I noticed that your input to the amp is on pin 3 (positive input). When I looked at the National Semiconductor datasheet, it shows an "AM Radio Power Amplifier" typical application where the input is on pin 2 (negative input). This is where I get confused — which is the proper input to use?

— George

A Look at the Equivalent Schematic on page 1 of the datasheet (Figure 3). You'll see that the + and - inputs are mirror images of each other — meaning they are interchangeable. What changes is the relationship of the input

■ FIGURE 3





■ FIGURE 4

waveform to the output. With the + input, the input and output are in phase; with the - input, the input and output are 180 degrees out of phase. Generally, the + input is used, but either will work.

MIRRORS YES, SMOKE NO

Q I'm looking for an advanced explanation — perhaps including some experiment suggestions — of the so-called diode-connected BJT and the current mirror. I've looked through all of my old college texts, the local community college library, and my county public library, with no success. I don't expect you to devote a full column, but any pointers that you may be able to supply would be greatly appreciated.

— Joseph F. Richmond

A For all intents and purposes, the diode-connected BJT (bipolar junction transistor) and current mirror are considered one and the same. While this circuit arrangement is often glossed over in college courses, without it the op-amp would never have come to see the light of day. In fact, the LM741 is riddled with them (you'll find one in Figure 3). Like you say, I don't have the ink to go into depth on the subject, but an overview I can do.

This design starts with a transistor whose collector is wired to its base — essentially a diode junction. The cool thing about a diode is that it maintains a fairly stable voltage across the junction even as the current through it varies. In effect, Rbias establishes a constant current (**Iref**) through the collector of Q1. Now if you couple the base of the first transistor to the base of a second transistor, Figure 4, you create a current mirror.

Whatever current flows through the base of Q1 also flows through the base of Q2, which, in turn, controls the current flowing through the collector of Q2. Here's where it gets interesting, because the current through Q2 (**Iload**) is equal to **Iref**. What's more, **Iload** is independent of the value of Rload!

Whether Rload is 1 ohm or 1,000 ohms, the current through it will always be equal to **Iref**. What we have here is a way to control the current through Q2 via Rbias. The circuit can also be rearranged for current sourcing — shown on the right — with no change in performance.

But the story gets even better. Theoretically, you can parallel as many Q2 transistors as you want — and they will all have the same collector current as Q1. Let's say you have a bunch of LEDs you want to light, and you want them all to be the same brightness. This is a challenge for most applications because the brightness of an LED is directly proportional to its current flow.

Sure, you could string them in series, but that increases the voltage by the forward drop of the LED multiplied by the number of LEDs. That is, four red LEDs in series need at least six volts; four blue LEDs ups the ante to almost 20 volts. When you only have five volts to work with, a current mirror (Figure 5) is simpler than a boost switching regulator. Moreover, you can mix and match the LED colors and not have to worry about their forward voltage drop.

Of course, nothing's perfect. In reality, the current flowing through Q1 is equal to the collector current plus the extra base current needed to drive Q2. This is why it's important that the gain of the transistors be as high as possible, typically 300 or more, to minimize the error.

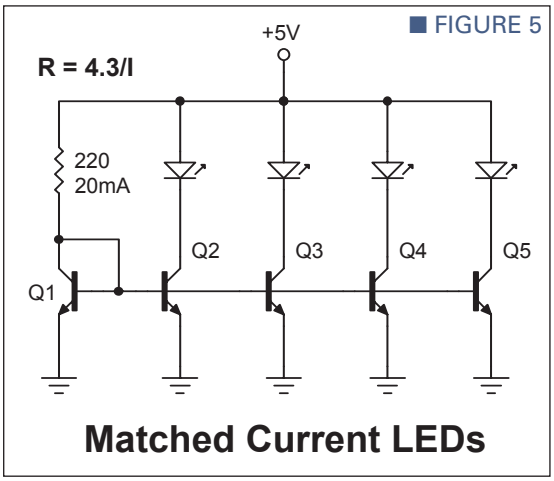
Other configurations have been devised — using additional transistors — to take the load off Q1's collector. Heat, too, plays a role because the forward voltage drop of the base-emitter diode is temperature-dependent, and unless the two transistors are at exactly the same temperature, you'll get an error. For further reading, go to the following websites.

www.4qdtec.com/csm.html

www.allaboutcircuits.com/vol_3/chpt_4/12.html

www.ece.cmu.edu/~ee321/spring99/LECT/lect17mar12.pdf

www.kettering.edu/~bguru/Pamp/PA-04.pdf



■ FIGURE 5

POWER SUPPLY DESIGN BOOKS

Q Regarding the question "Transformer Ratings, Again" in April '06, you showed a group of very useful equations. I would like to go with more detailed theoretical analysis and mathematical equations. I

am very interested to know full details about rectifier design. Could you please direct me to a good text book (old or new) for that purpose?

— M.J.

A Here are two books that go into depth on the subject. Both are available from **Amazon.com**.

• *Power Supply Cookbook*, Marty Brown, Second Edition.

• *Reference Data For Radio Engineers* 1977. Chapter 14.

RECYCLING LASER PRINTERS

Q The laser column has been gone for years, and I miss it. New laser printers are so cheap these days, many are being discarded rather than repaired. Do you know of any hobby use for the laser parts?

— Tom Grabowski

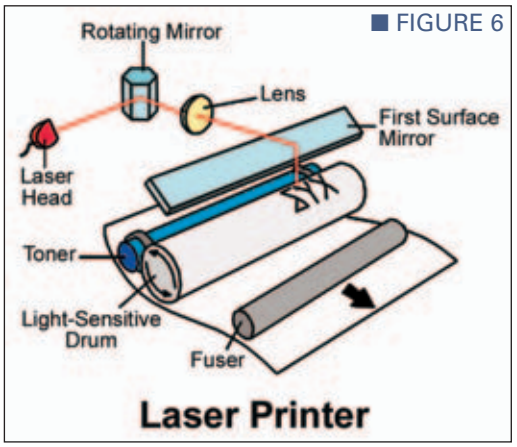
A First, you have to make sure you have a real laser printer and not an LED printer, which uses the same paper feed and drum mechanism. The construction of a genuine laser printer is shown in Figure 6. Look for the rotating/spinning mirror.

How does it work? When you send an image of a document or a picture to the printer, a low-level laser beam "draws" the image on the drum using rotating optics. It generates a negative electrical charge — an electrostatic image. (In some printers, this works with the charges reversed — that is, a positive electrostatic image on a negative background.)

As the drum continues to rotate, it passes the toner cartridge. The toner contains a fine black powder, which clings to the electrostatic image created by the laser on the drum. It then rolls over the paper, which has been given an even stronger electrostatic charge, and impresses the pattern onto the paper. At this point, a whisper can blow the powder off the paper and smear the image or create blotches. The paper then passes through a fuser — heated rollers which melt the powered toner onto the paper.

So what can you salvage from this? Generally, the rollers are the first to fail. These can be replaced from a maintenance kit that runs between $20 and $50 for most printers — kits that let you DIY (from **www.fixyourownprinter.com/kits/all** — among others). However, the technology is advancing so fast that the choice between buying a new printer versus repair usually results in the old printer being discarded at this point. What's left are the cool stepper motors — make sure you scrounge the driver electronics, too — and a low-power solid-state laser diode that's likely on its last leg. Also be aware that this is a strobed laser with a very low duty cycle.

Now, if you're lucky enough to run across a newer laser printer, you'll find an array of multi-beam laser diodes — not the LED diodes I warned you about earlier. Each diode can output as much as four watts and be multiplexed in any pattern you can imagine. I haven't had the time to continue this path. But if you do, I'll be glad to publish what you discover.



■ FIGURE 6

WORKING WITH LDO REGULATORS

Q Some time ago, you suggested an ICL7663 adjustable voltage regulator for a battery operated application. And it worked great. Now I have another application that has the same requirements — except for size. I'm limited to a very small case. I'm using a PIC16F628 and a nine-volt transistor battery. Is there a low-power voltage regulator that does not require all of the resistors and caps of the ICL7663 design? Maybe an LDO volt regulator is what I'm hoping for. Any suggestions?

— Brad

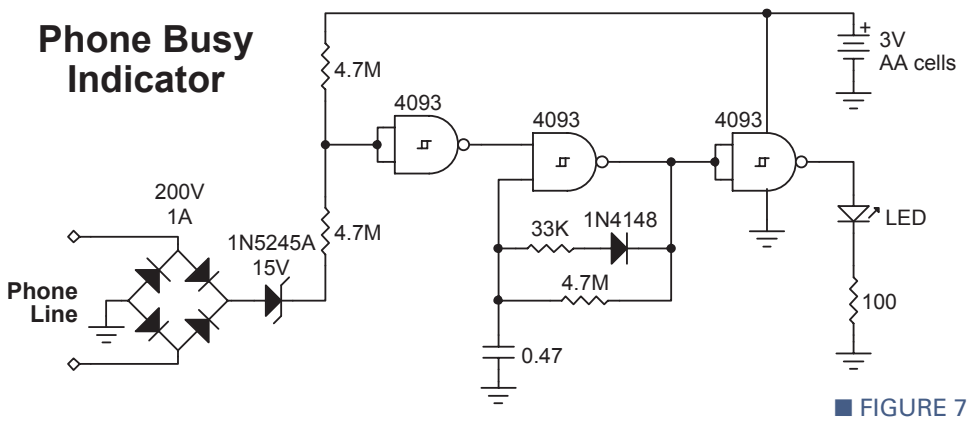
MAILBAG

Dear TJ,

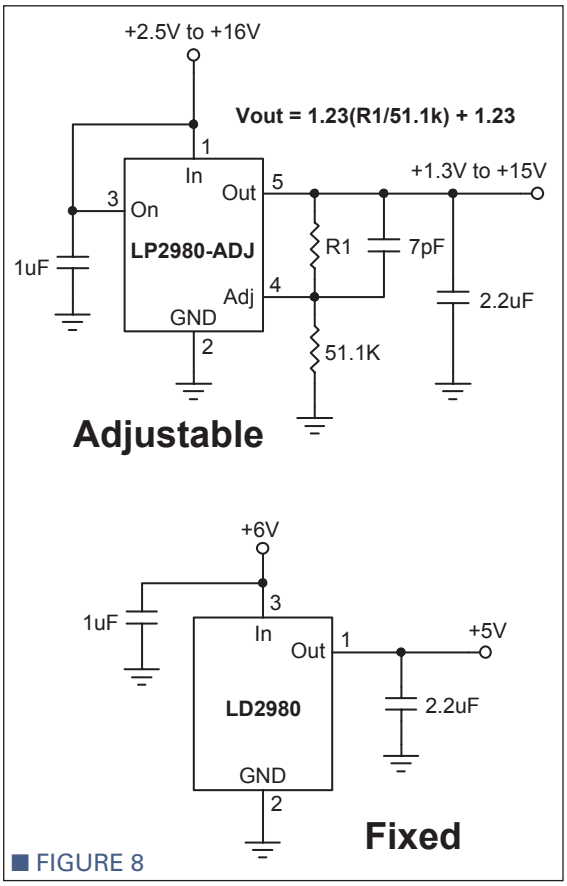
I need help regarding the "I'm Busy!" phone-line indicator in the March '06 issue. I have built two of these and can't get them to work. I have tried several 4093 chips, components and double-checked the soldering. The output of the bridge goes from -50.1 volts "on-hook" to -8.8 volts "off-hook," which is normal. If you have any suggestions, please let me know.

— Roger Hamel KG8XC

Response: *The bridge rectifier is backwards. Here is the corrected schematic (Figure 7). — TJ*



■ FIGURE 7



■ FIGURE 8

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A The LDO (low-dropout) voltage regulator is probably the most misunderstood of all voltage regulators. Many users think that because the voltage between the input and the output is 200 mV or less, it will save power. Not true. Let's use your nine-volt battery as an example. The 16F628 normally works at five volts and draws about 2 mA. That means that somehow or another you have to shed four volts. All linear voltage regulators — including LDOs — do that by inserting a series resistance between the battery and your PIC.

Simple math (P = EI) tells us that 8 mW has to be wasted across the regulator as heat — even across an LDO regulator. Since the PIC dissipates 10 mW on its own, the wasted power amounts to almost half the power your battery has to give.

But that's only half the story. Let's take the 78L05, for example. Not only must it dissipate your four volts, but it consumes 3 mA even when it's not doing anything but sitting there. Math says that with a nine-volt battery, that's another 27 mW of wasted power. This is why the LDO was invented. To reduce this wasted battery power.

The proper way to use an LDO is to match the input voltage to the output voltage. The less voltage the regulator has to waste, the more efficient your design and the longer the battery will last. For example, if you replace the nine-volt battery with four AA cells or two lithium cells — which equal six volts — the voltage drop becomes one volt. One volt at 2 mA is just 2 mW, a four-fold gain.

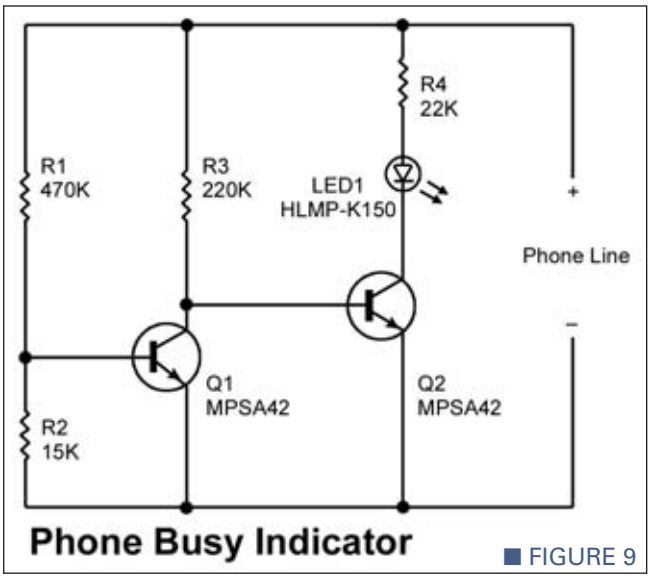
Another benefit of LDO voltage regulators is their low standby current — which can be as low as 10 µA. The LP2980 requires just 100 µA at 2 mA. Adding up the numbers, it comes to 2.1 mW of operating power — a far cry from the 35 mW demanded by a 78L05.

I've designed and built lots of 16F628 circuits, and found the LD2980 (from STMicroelectronics) to be most useful. It has a low 100 µA quiescent current, 120 mV voltage drop, and a small SOT-89 footprint. It also comes in many different fixed-voltages, making it easier to match the voltage drop to the battery size (the 16F628 has a Vcc range of 3.0 to 5.5 volts; 2.0 to 5.5 volts for the 16LF628) for best efficiency. When I needed an adjustable voltage source, I used the LP2980-ADJ. Figure 8 shows both designs.

READER'S CIRCUIT: PHONE BUSY INDICATOR

I have a circuit (Figure 9) which is simpler than the one published in the March '06 issue. It has fewer components, and is powered by the phone line, so there is no battery. The transistors are high-voltage types, to withstand the ringing voltage, and the LED is low-current. There is no diode bridge, as this interface cannot be used here in the UK. The phone company employs automated testing, and one test involves a low-voltage reverse polarity leakage test. If this circuit is used with a diode bridge, it would upset the testing, which would continue ad infinitum, flashing the LED every few seconds. The circuit is taken from my book *Telephone Installation Handbook*.

— Steve Roberts
Bude, Cornwall England



■ FIGURE 9

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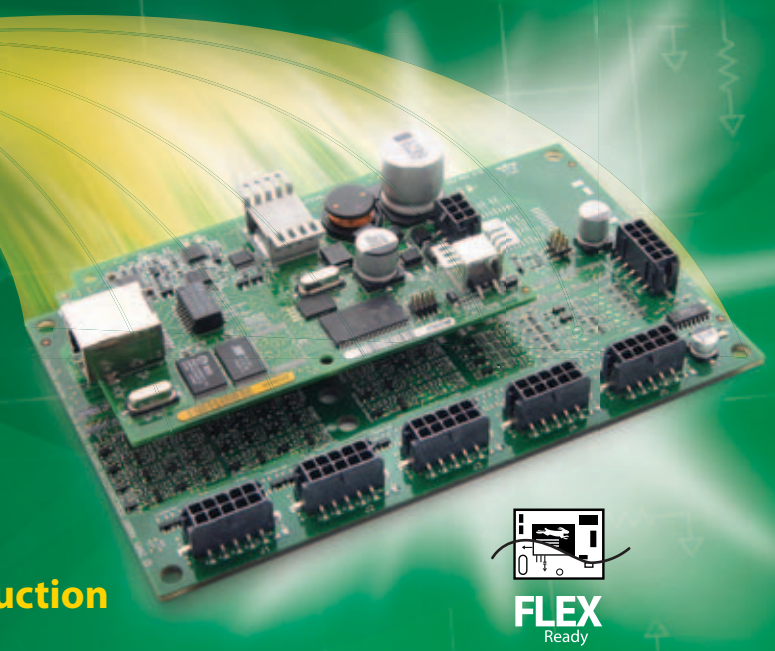

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Solutions That Work

■ BY CHUCK HELLEBUYCK

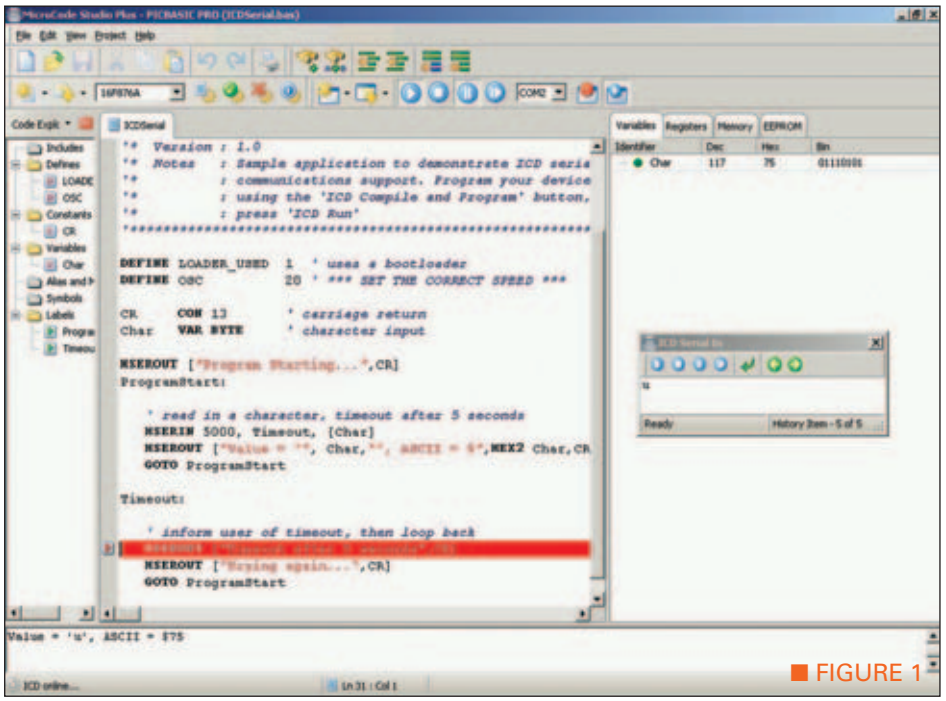
DEVELOPING WITH A PIC BOOTLOADER

IF YOU'VE BEEN A REGULAR READER OF THIS COLUMN and have started to actually program PICs, you are probably tired of moving the PIC from programmer to project and back again every time you make a change. It not only damages pins, but can sometimes cause confusion if the PIC is put in the board backwards or even shifted by one pin. This is why I like to develop with a bootloader and it's one of the most difficult items to explain to a beginner.

A bootloader is software pre-installed in the PIC that allows you to program the PIC in-circuit so you don't have to remove it over and over again. Unfortunately, not all Microchip PICs allow you to use a bootloader. But as new parts are released, many of them have the bootloader capability. The PIC16F876A I've been using in these columns is bootloader-capable and one of the reasons I picked it for these articles.

WHAT IS A BOOTLOADER?

When you write your PIC program in PICBasic, Atom Basic, Assembly, C language, or any other compiler, it will eventually become a binary file of 1s and 0s, also known as a .hex file. There are really two ways to load or program this binary file into a Microchip PIC: with a PIC hardware programmer like the EZPIC Programmer I talked about back in January or let the PIC program itself, using a bootloader program, pre-installed in the PIC's memory (this is how the Atom modules get programmed).



■ FIGURE 1

Option 1 — PIC Programmer Module

A PIC hardware programmer is a custom-designed module that receives the binary code file, created by the compiler, via a PC serial or USB port. The PIC programmer module then generates the electrical signals the PIC needs to see and downloads the program to the PIC through the Data and Clock pins on the PIC (B6 and B7 on the PIC16F876A). This is how the EZPIC programmer works and lots of other PIC programmers.

Option 2 — Bootloader

A bootloader is a custom binary file pre-loaded in the PIC memory that allows a PIC to program itself without use of a hardware PIC programmer discussed in Option 1. It does this with special circuitry built inside the PIC that generates the necessary voltages internally. The PIC receives

the binary file through its serial port and then programs the internal program memory (without overwriting the bootloader code).

The bootloader software only runs for about a half second. If it doesn't see a new program arriving at the serial port connection, it just jumps to the program that is in its program memory and runs that program. The catch is you need to get the bootloader binary file into the PIC first before you can run it. This means you have to either buy a PIC with a bootloader programmed in or program a blank PIC with the bootloader binary file using a PIC hardware programmer module. So, in other words, you need Option 1 in order to get to Option 2.

There are numerous bootloaders available via the Internet, and many of them are free. They will include a program that runs on the PC to send your PIC program out the serial port and also the .hex file of the bootloader for the PIC you plan to use. A good, free one is at **www.microchipC.com** called PICLoader. I've used it many times and so have many other people. In fact, one of the readers of this column — Ron Zlotnik — used this bootloader and one of my RS232 breadboard modules to make a PIC16F876A bootloader that he uses with PICBasic Pro. You can read Ron's instructions on how to do it at my website through the link **www.downtowninternet.com/elproducts/picloader.htm**

MCLOADER

If you are willing to spend a little money and you use PICBasic Pro, then I recommend the MCLoader from mecanique (**www.mecanique.co.uk**). The reason I suggest this bootloader for the PICBasic Pro user is that this bootloader also adds the option of running with the MCStudio Plus in-circuit debugger. The debugger allows you to step through your PICBasic Pro code command-by-command and watch the registers and variables change after every command. It's very similar to the in-circuit debugger included with the Atom module software that I've talked about in previous articles.

The MCLoader is included with the MCStudio Plus software and it gives you the .hex bootloader files for many of the PICs that will run a bootloader. The MCStudio standard version comes with PICBasic Pro and you can download it for free from the mecanique website. The Plus version — which includes the MCLoader and in-circuit debugger — costs $49.95, but to me is well-worth the money. Let's take a look at why this is such a great tool for the PICBasic Pro programmer and why I recommend it.

USING MCSTUDIO PLUS

When you write a program, you are probably running through the program flow in your head figuring out what the variables are doing after every command. Then when you actually run the program and it doesn't work, you start to think about the program over and over again in your head trying to figure out why it isn't doing what you thought it should.

If you could only have the ability to run the program and watch each command execute. Better yet, what if you could have the program run at close to normal speed, but then automatically stop at a particular command so you can execute that one slowly and determine why the variable or output pin isn't doing what you expect? That is what an in-circuit debugger does for you.

In Figure 1, you see the MCStudio Plus screen, which is very similar to the MCStudio standard version included with PICBasic Pro. The MCStudio Plus screen in Figure 1 also shows the in-circuit debugger running a program. Notice how one of the lines is highlighted in red. The highlighted line is a breakpoint that I set. The program ran until it got to that line and then stopped.

On the right part of the screen are four tabbed displays. The first one is the variables tab and it shows the variable "Char" used in the program.

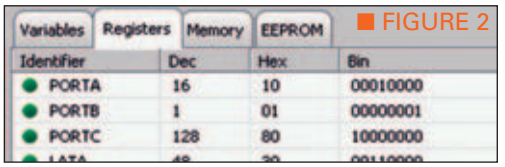


FIGURE 2

The value of "Char" is shown in Decimal, Hexadecimal, and Binary format at the point just prior to executing the command highlighted in red. If you wanted to see the output port registers inside the PIC, such as PortB, you would click on the Registers tab as seen in Figure 2.

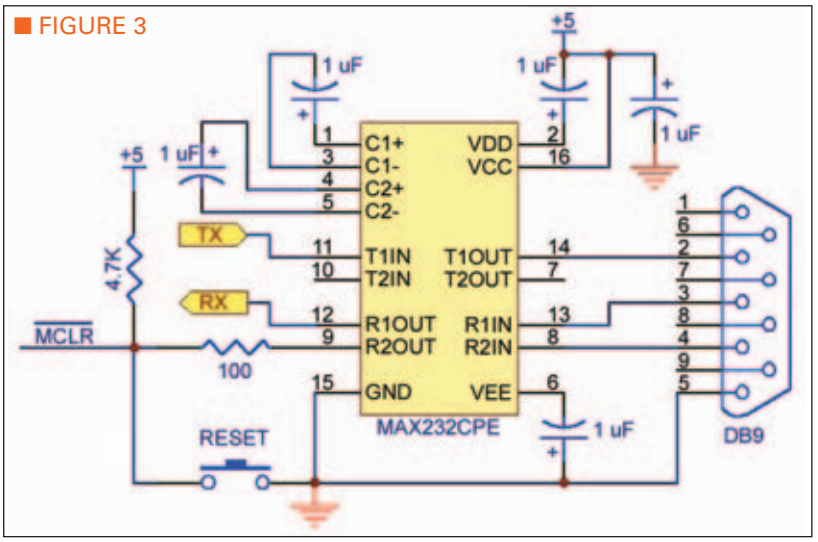
PortA, PortB, and PortC are shown in Decimal, Hexadecimal, and Binary format. If you have a command that is reading the port or driving the port pins, then you can use this to see the status of the pins before or after the command executes. You see how useful this can be?

SAMPLE PROGRAM

Included with the MCStudio software are a couple sample programs written in PICBasic Pro that work great with the in-circuit debugger. One of them is shown in the program listing as the program ICDSERIAL.BAS. The reason I left this in its present form was because it was such a great demo file. It uses the HSEROUT/HSERIN commands. In a previous article, I showed how to use the SEROUT/SERIN commands and just touched on the HSEROUT/HSERIN commands. Because the MCLoader bootloader uses the C6 and C7 pins of the PIC16F876A, we can easily use these commands with the bootloader. This is because the hardware serial port of the PIC16F876A is connected to the C6 and C7 pins. This allows the PIC to receive and send data through the same bootloader connection back to the PC and the in-circuit debugger software.

The software sample program simply receives an ASCII value from the PC serial port, which you enter into the keyboard, and displays it on the in-circuit debugger's bottom display window. When the HSERIN command is run, the in-circuit debugger automatically brings up a serial communication window on the PC

■ FIGURE 3



which can be seen on the right of Figure 1. I entered the letter "u" and hit the enter key. At the bottom of Figure 1, you see that the letter "u" was received and the hexadecimal value of "$75" is shown next to it. This is the ASCII value for the small case letter "u." Notice that you can also see that value shown in the variable "Char" on the right of Figure 1 in the variables window.

All this sample program does is receive an ASCII value from the PC and then send back the hexadecimal value to be displayed on the bottom of the screen. This could easily be modified to drive an LCD display once you've proved the communication code works with the in-circuit debugger. Do you see how great this tool is?

BOOTLOADER LIMITATIONS

Because the bootloader has to know what frequency it's running at to properly communicate with the PC serial port, the bootloader can only be set at one frequency. For example, if you have a bootloader running on a PIC at 20 MHz, your program won't run properly if you compiled it for 4 MHz operation. You have to adjust your program to run at the bootloader speed or re-install a new bootloader that runs at 4 MHz. Most of the bootloader .hex files included with MCLoader offer a 20 MHz and 4 MHz resonator version for each PIC supported. They will even create a unique frequency version for you if you email them.

At the top of the sample program are two lines shown below.

```
DEFINE LOADER_USED  1     ' uses a bootloader
define OSC    20          ' *** SET THE CORRECT SPEED ***
```

SAMPLE PROGRAM

```
'*****************************************************************
'*  Name    : ICDSERIAL.BAS
'*  Author  : David John Barker
'*  Notice  : Copyright (c) 2002 Mecanique
'*          : All Rights Reserved
'*  Date    : 26/02/02
'*  Version : 1.0
'*  Notes   : Sample application to demonstrate ICD serial
'*          : communications support. Program your device
'*          : using the 'ICD Compile and Program' button,
'*          : then press 'ICD Run'
'*****************************************************************

DEFINE LOADER_USED  1     ' uses a bootloader
define OSC    20          ' *** SET THE CORRECT SPEED ***

CR     con 13             ' carriage return
Char   var byte           ' character input

hserout ["Program Starting...",CR]
ProgramStart:

   ' read in a character, timeout after 5 seconds
  hserin 5000, Timeout, [Char]
  hserout ["Value = '", Char,"', ASCII = $",hex2 Char,CR]
  goto ProgramStart

Timeout:

   ' inform user of timeout, then loop back
  hserout ["Timeout after 5 seconds",CR]
  hserout ["Trying again...",CR]
  goto ProgramStart
```

The first one "DEFINE LOADER_USED 1" is needed to tell the PICBasic Pro code to jump to the bootloader at start-up rather than run the program. When you program a blank PIC with this same file and don't want to run a bootloader, you just comment out this line. The second line sets the oscillator speed to match the bootloader speed.

You also have to add the RS232 level shifter circuit to get the MCLoader to work. Figure 3 shows a recommended schematic from Reynolds Electronics (**http://rentron.com**), which is also shown on the mecanique website. It's really just a standard RS232 inverter chip circuit that I also use in my RS232 breadboard module that Ron Zlotnik used in his setup. I built the same circuit into my Ultimate OEM module so I could use my module in-circuit and program it with a bootloader and also run the MCStudio Plus in-circuit debugger when I'm developing code. This allows me to develop designs without having to pull the chip out and then plug it back in many times while I try to figure out why my program won't work. If you are writing simple programs, then this setup may not be a lot of help. When you get into larger programs, though, this type of tool is priceless.

The TX pin in the schematic connects to the PIC's C6 pin. The RX pin of the schematic connects to the C7 pin. The MCLR wire of the schematic connects to the MCLR pin of the PIC. When you first try to download, it will give a message that the bootloader cannot communicate. This is when you press the reset switch

which starts the PIC up again in bootloader mode, ready to receive your program.

TAKING IT FURTHER

Another feature I like about this type of setup is the ability to use the PIC16F876A to develop small PIC projects. One of the great advantages to the PIC microcontrollers is their common architecture. Many of the PICs share the same I/O and peripheral structure. This means if a program works on a 16F876A, with very little modification, you can make it work on a smaller PIC with the same peripherals. In Figure 4, I show how I jumpered the I/O of my Ultimate OEM module to an 18-pin PIC development board. By matching up the proper I/O pins, I can develop a project on an 18-pin board without having to use an 18-pin PIC. Later on, I can recompile the code and actually use an 18-pin PIC, but I will have debugged 99% of the code using this method. This is great because a lot of the smaller PICs don't offer the bootloader option.

NEXT STEPS

I highly recommend you get a bootloader to work with a PIC16F876A or similar. Even if you just use the directions Ron wrote out for the PICLoader, you won't have to spend a lot of money. You don't have to use my RS232 bootloader module, either. You can find them from various sources — such as eBay (**www.ebay.com**) — or just build your own. RS232 chips can be found at various electronic suppliers — such as Jameco (**www.jameco.com**) — for under $2.00.

If you did the project on serial communication from several issues back, you probably already have the circuitry ready to roll; you just didn't know it could help you program the PIC in-circuit also.

I hope I've helped clear some of the confusion about bootloaders without adding more. It's just a great method to use and industry is using this for field programming more and more.

As usual, if you have questions or comments, send them to me at chuck@elproducts.com Also, if you are attending the Microchip Masters Conference in July, look me up — I'll be out there getting training, myself. **NV**

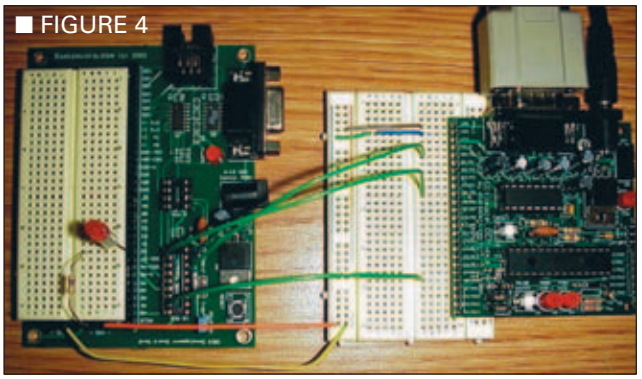


FIGURE 4

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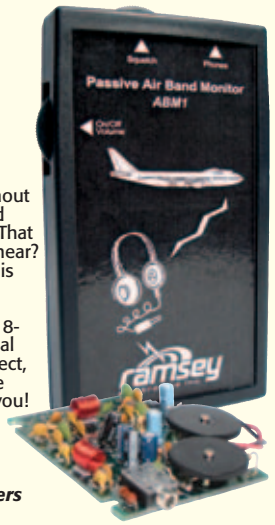
- ✔ **Passive design, can be used on aircraft, no local oscillator, generates and creates no interference!**
- ✔ **Great for air shows**
- ✔ **Patented circuit and design!**



For decades we have been known for our novel and creative product designs. Well, check this one out! An aircraft receiver that receives all nearby traffic without any tuning. It gets better... there is no local oscillator so it doesn't produce, and can't produce, any interference associated with all other receivers with an LO. That means you can use it onboard aircraft as a passive device! And what will you hear? The closest and strongest traffic, mainly, the one you're sitting in! How unique is this? We have a patent on it, and that says it all!

This broadband radio monitors transmissions over the entire aircraft band of 118-136 MHz. The way it works is simple. Strongest man wins! The strongest signal within the pass band of the radio will be heard. And unlike the FM capture effect, multiple aircraft signals will be heard simultaneously with the strongest one the loudest! And that means the aircraft closest to you, and the towers closest to you! All without any tuning or looking up frequencies! So, where would this come in handy?

1. ***At an air show! Just imagine listening to all the traffic as it happens***
2. ***Onboard aircraft to listen to that aircraft and associated control towers***
3. ***Private pilots to monitor ATIS and other field traffic during preflight activities (saves Hobbs time!)***
4. ***Commercial pilots to monitor ATIS and other field traffic as needed at their convenience***
5. ***General aircraft monitoring enthusiasts***

Wait, you can't use a radio receiver onboard aircraft because they contain a local oscillator that could generate interfering signals.

We have you covered on that one. The ABM1 has no local oscillator, it doesn't, can't, and won't generate any RF whatsoever! That's why our patent abstract is titled "Aircraft band radio receiver which does not radiate interfering signals". It doesn't get any plainer than that! Available as a through-hole hobby kit or a factory assembled & tested SMT version.

SPECIFICATIONS

Frequency Range:	118 MHz to 136 MHz
Receiver Type:	Patented Passive Detector
IF Frequencies:	None!
Receiver Sensitivity:	Less than 2 uV for detectable audio
Audio Output:	700mW, 8-24 ohms
Headphone Jack:	3.5mm stereo phone
External Antenna:	Headphone cord coupled
Power Requirement:	9VDC battery
Dimensions:	2.25" x 2.8" PC Board 2.5" x 4.6" x .9" Case
Weight:	4 oz. with battery

ABM1 **Passive Air Band Monitor Kit** **$89.95**
ABM1WT **Passive Air Band Monitor, Factory Assembled & Tested** **$159.95**

Digital Tuned High Performance Aircraft Band Receiver

New For 2006

- ✔ **Rock solid dual conversion PLL receiver!**
- ✔ **Airport runway lighting controller output!**
- ✔ **4 user memory scanner banks, 20 freq's each**
- ✔ **Full band scanner with skip and skip/timer modes**
- ✔ **Internal front panel speaker**
- ✔ **External antenna input, speaker out, headphone out**
- ✔ **Stylish and shielded black metal enclosure**
- ✔ **Available as a hobby kit or factory assembled & tested**

Professional features at a hobbyist price! To begin with, we designed it with the latest technology, utilizing a rock stable synthesized PLL dual conversion receiver. We gave it superb image and adjacent channel rejection to allow you to lock onto the signals you want and not to be bothered by those you don't!

Once we got the RF portion designed we took a close look at the features desired in such a receiver. We gave it a neat 2x8 line LCD display to show you all the functions. Control of modes and setups is obtained through the front panel controls and confirmed on the LCD display. On/Off/Volume and Squelch controls are also provided on the front panel. We even gave it a front panel speaker in case you stack the lighting controller or something else on top of it! So far we've described the ultimate aircraft receiver that's not only the perfect field monitor for a hangar or airport manager's office, but for the serious enthusiast. Can it get any better than that? It sure can!

SPECIFICATIONS

Frequency Range:	117.975 MHz to 137.000 MHz 25kHz steps
Receiver Type:	Dual Conversion PLL
IF Frequencies:	10.7 MHz & 450 kHz
Receiver Sensitivity:	Less than 1 uV across the band
Image Rejection:	Greater than -80 dB
Adjacent Ch. Rejection:	Greater than -40dB
Scanner Banks:	4, 20 frequencies each
Audio Output:	1 watt, 8 ohms
Light Controller Output:	3 events, 5 events, 7 events output to controller
Power Requirement:	12VDC, 500mA
External Antenna:	BNC female, rear panel
Dimensions:	5.55"W x 6.45"D x 1.5" H

The top request we've had for a professional aircraft receiver was to embed automatic runway lighting control. Consider it done! The lighting controller follows the standard protocol for remote runway lighting. The pilot "keys" his microphone on the local CTAF channel for the specified number of times. All you need to do is set the receiver for the lighting control mode, then make sure the squelch is closed and will open on a suitably strong signal. Typically the number of "keys" or "events" according to the receiver control the lighting as follows: 3 events, 25% brightness; 5 events, 50% brightness; and 7 events, 100% brightness. The AR2's adjustable lighting timer sets turn-on duration to your needs. Includes the matching case and knob set and power supply. For the aviation professional that is not interested in building the receiver, the AR2 and the lighting controller are also available factory assembled and tested, ready to go. Just plug it in and you're all set.

AR2 **Synthesized Aircraft Receiver Kit With Case & AC Power Supply** **$199.95**
AR2WT **Factory Assembled & Tested AR2 Synthesized Aircraft Receiver** **$269.95**
AR2L **Plug-In Runway Lighting Controller Interface Kit With Case & AC Power Supply** **$59.95**
AR2LWT **Factory Assembled & Tested AR2L Runway Light Controller** **$99.95**

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SOL5N **Solar Trickle Charger** **$26.95**

20W Sub-Mini Audio Amp

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BS2C **Bullshooter-II Kit** **$69.95**

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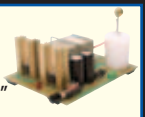
Generates a steady state DC voltage, 7.5kV DC negative, 400uA! That's lots of Ions! Feel the constant blast of fresh air from the air cannons! Runs on 12VDC or our PS adapter.

IG7 **HV Ion Generator Kit** **$64.95**

Plasma Generator



Provides a stunning 25kV at 20kHz from a solid state circuit! Build your own plasma bulbs, generate 2" sparks and more! Runs on 16VAC.

PG13 **Plasma Generator Kit** **$64.95**

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Produces impressive laser light shows just like the big boys do! Variable pattern and speed controls and an audio input to modulate the show to your music! Uses standard laser pointers included.

LLS1 **Laser Light Show Kit** **$44.95**

LED Strobe Light

Say goodbye to the fragile glass Xenon tube! High power LED's produce super bright strobe displays. Variable flash rate and audio input to sync the flash to your music. Runs on 12VDC.

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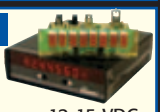
Signal Magnet Antenna

Super Hi-Q ferrite rod antenna with Faraday shield pulls in the signal and removes the noise! Great results from 500kHz to 15MHz. Super for the AM broadcast band...no more noise! Includes power supply.

SM100 **Signal Magnet Kit** **$89.95**

Touch Tone Reader



Captures dialed phone numbers, repeater codes, control codes or anything that uses Touch Tone! Phone line and audio inputs. Runs on 12-15 VDC.

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Tickle-Stick Shocker

Extremely popular kit, produces a pulsing 80V tickle output with a telltale blinking red LED! And who can't resist a blinking light! Great fun for your desk! Runs on 3-6VDC.

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- ✔ Line level inputs and output!
- ✔ Microprocessor controlled!
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A cut above the rest, the FM25B features a PIC microprocessor for easy frequency programming without the need for look-up tables or complicated formulas! The transmit frequency is easily set using DIP switches; no need for tuning coils or "tweaking" to work with today's "digital" receivers.

Frequency drift is a thing of the past with PLL control making your signal rock solid all the time - just like commercial stations. Kit comes complete with case set, whip antenna, 120 VAC power adapter, 1/8" Stereo to RCA patch cable, easy assembly instructions, and the SMT parts are factory preassembled - you'll be on the air quick! *(Note: The end user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body).*

FM25B **Professional Synthesized FM Stereo Transmitter Kit** **$139.95**

Digital Synthesized FM Stereo Transmitter

- ✔ The newest Ramsey transmitter!
- ✔ Rock stable PLL synthesized
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- ✔ Professional metal case
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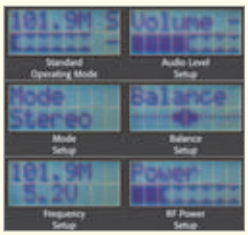
You told us what you wanted, and we listened! The legacy continues with the latest Ramsey transmitter, designed from the ground up to YOUR SPECS!



The FM30 is designed around an RF tight vinyl clad metal enclosure for noise free and interference free operation. All settings are done without taking the cover off! Enter the setup mode from the front panel and step through the menu to make all of your adjustments. A two line LCD display shows you all the settings! In addition to the LCD display, a front panel LED indicates the PLL lock so you know you are transmitting. Besides frequency selection, front panel control and display gives you 256 steps of audio volume (left and right combined) as well as RF output power. A separate balance setting compensates for left/right differences in audio level. In addition to settings, the LCD display shows you "Quality of Signal" to help you set your levels for optimum sound quality. And of course, all settings are stored in the non-volatile memory for future use!

The design includes EMI filters on line level audio and power inputs, and a state of the art microstrip PCB inductor to reduce microphonics for the ultimate in alignment free operation. RF output is through a professional well shielded rear panel BNC connector for a perfect antenna match. Standard RCA connectors are used for left and right line level audio inputs.

The FM30 operates on a 13.8 to 16VDC and include a 15VDC plug in power supply. The stylish metal case measures 5.55"W x 6.45"D x 1.5"H and is a perfect match with your computer to broadcast your music files throughout your house. If you're looking for a super performer without all the features of our FM100 series transmitters, the new FM30 is for you! *(Note: The end user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body).*

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The unique design allows unprecedented super high resolution measurements and display of absolute atmospheric air pressure. The UP24 senses ambient air pressure and critically calculates elevation with unheard of precision! Using a highly sensitive sensor and 24-bit A/D converter in a special noise-immune design, less than 1/3" of an inch of elevation resolution is achieved! YES, we said 1/3 of an inch! This high accuracy and resolution opens the door to a host of sophisticated environmental air pressure monitoring applications.

Unlike your normal run-of-the-mill barometer, air pressure is sensed in Pa's or kPa's. What are those you may ask? Pascals or KiloPascals. However, don't be afraid, for your convenience, and to fit any application you may have, it is also displayed in millibars, bars, PSI, atmospheres, millimeters of mercury, inches of mercury, and feet of water! Take your pick! The range of the UP24 is 15kPa to 155kPa.

We've talked about air pressure, now let's talk about elevation! The incredibly precise 24 bit A/D converter in the UP24 looks at the air pressure and converts it to elevation above sea level. In both graph and text, the elevation is displayed to a resolution of 1/3"! Yes, I said 1/3 of an inch! The applications for the super accurate elevation meter are endless. From watching and recording elevations during hiking trips to measuring and recording the wave heights on boats! Let your imagination take over from there!

What if you're in the field and you want to save data captured in your UP24? The built-in FLASH storage provides 13,824 samples of storage. Then you can transfer your data to your PC with a standard USB interface.

While the UP24 is small enough to be kept in your coat pocket it boasts a large 2.78" x 1.53" 128x64 pixel LCD display screen making viewing easy. Display modes include both realtime pressure and elevation graphs as well as pressure and elevation statistics. There are 12 user selectable sample rates from 1/10th of a second all the way up to every 15 minutes.

Needless to say, you cannot put all the specs and screen shots in the limited space of this ad! Visit our website at www.ramseykits.com for full specs and information.

If you're looking for the finest air pressure and elevation sensor, check out the UP24, truly a marvel in the industry! Available in a ready-to-build kit or a factory assembled and tested version. Check our website at www.ramseykits.com for more information!

UP24	**High Resolution Air Pressure/Elevation Sensor Kit**	**$239.95**
UP24WT	**Factory Assembled and Tested UP24**	**$299.95**
AC125	**110VAC Power Adapter/Charger**	**$9.95**

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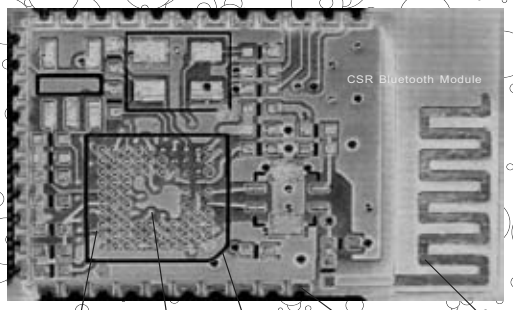

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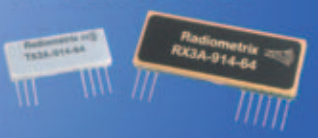

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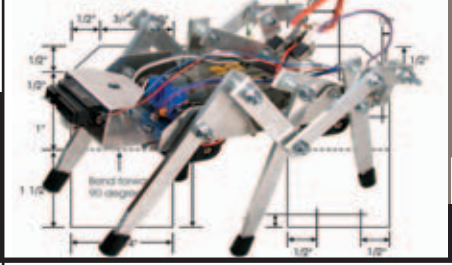


■ BY PHIL DAVIS

DESIGN A MINI SUMO — PART 1

LAST SPRING, OUR ROBOTICS CLUB scheduled a Mini Sumo competition for the summer of 2005. Of course, no one had a Mini Sumo robot, so a mad frenzy of ideas, concepts, and parts ensued.

For the uninitiated, Mini Sumo competitions take their name from the Japanese form of wrestling called Sumo. In this case, two robots combat for three minutes in a black ring 77 cm (just over 30 inches) in diameter, bounded by a one-inch border. Each robot attempts to locate the other and push it off the edge.

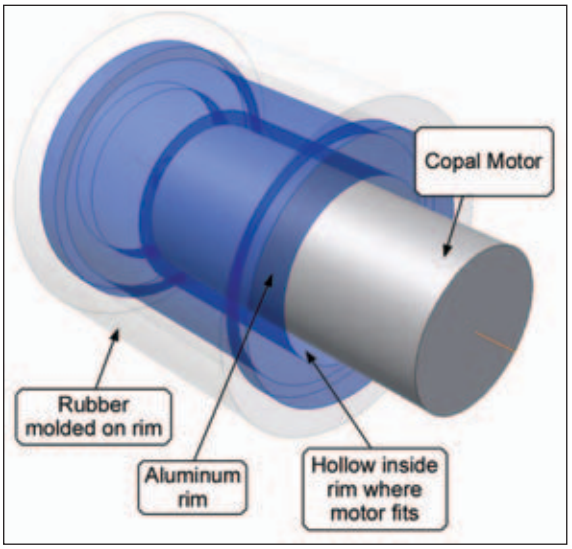
At the time the competition was announced, our club used what we called "Brandon's" board, which was a small Atmel Mega16-based system with motor drivers, sensor ports, switches, and LEDS designed by (you guessed it) Brandon. So, the "what to use for a microprocessor" part was covered. That left:

• What to use for the chassis, motors, wheels, and sensors?

• What to use for software and how to write the program?

Many of the club members chose to use an off-the-shelf chassis for their Mini Sumos — such as the Mark III — and, while this is an excellent choice, my thoughts were that if everyone uses the same "kit," then everyone will perform approximately the same — at least mechanically. To be different and have a better chance to win, you need to do something different.

This started me thinking about what exactly would make a good Mini Sumo. If one were to stand a better than average chance of winning, how exactly would one go about designing a Sumo and what would one use for software? That's what it's about — winning! So, here in Part 1, I want to take you through the steps and the processes for designing the mechanical side of my bot and in Part 2, I will go over the software I used and the program I wrote. I should issue a brief disclosure here: not all these ideas originated with me; I did extensive searching on the Internet and brought together many ideas, as well as some of my own.



■ PHOTO 1. CAD drawing of the completed wheel system.

THE MINI SUMO CHASSIS

The basic function of the chassis is to serve as a platform which rigidly supports wheels, motors, sensors, electronics, and batteries. In addition, it must conform to the Mini Sumo rule constraints:

• It must fit into a "box" 10 cm long by 10 cm wide (3.93" x 3.93"), but may be an arbitrary height.

• It must weigh between 0 and 500 grams (0–1.1pounds).

But what other functionality should it have? Well, to think about this, we need to understand the fundamental objectives of the competition which are finding the opponent, pushing the opponent out of the ring, not getting pushed out, and not falling off. If we prioritize these objectives, we see the following order:

• Don't fall out of the ring.
• Don't get pushed out of the ring.
• Locate the opponent.
• Push the opponent out of the ring.

Considering these priorities gives us some ideas about the direction of the design. To prevent an accidental drive off the edge of the ring will require sensors looking downwards for the white perimeter line on both the front and rear of the robot. These will also help us — if possible — to avoid being pushed out of the ring. Locating the opponent requires another sensor, but a different kind. What we need here is a distance sensor, something which will allow the robot to look across the ring and see if there

is an object (opponent) in its view.

Finally, this brings us to attacking our opponent, and the only thing at hand to do that is the 'bot itself. This means we must make the best of what we have and shape the chassis as much as possible so that it will be the most efficient at pushing the other 'bot out of the ring. I think there are several strategies here which we can bring to bear to accomplish this.

MECHANICAL STRATEGIES

The first thing we should consider is the amount of friction our wheels will have with the surface of the Sumo ring. This is important for two reasons. The first is that when we attack our opponent, we will need to push as hard as possible without having our wheels slip. In effect, we need to "out friction" the other guy so he is the one slipping. Next, when our opponent is attacking us, we want to hold our ground and not be pushed across the ring. Again, we need to "out friction" the other guy. I believe accomplishing this is all about wheel surface area and wheel surface "gooeyness" (that's a technical term).

The second consideration involves the best way to "unstick" our opponent; that is, break the friction they have between their wheels and the surface of the ring. The solution to this is hinted to in the previous sentence "break the friction they have between their wheels and the surface." And the best way to do that is to get under them and lift at least one wheel off the ground. If we can do that, it will mean they will easily slide across the surface and off the edge (we hope).

Conversely, a third strategy has to be not letting the opponent get under our 'bot and lift a wheel off the ground. This would be disastrous and leave us vulnerable to being pushed out of the ring.

The next strategy is speed. Yes, speed. You might think that moving slowly and "strongly/powerfully" would be the answer, but not necessarily so, especially during the launch of the attack. Consider this simple formula we all learned in high school physics: k = m*(v *v), in English: kinetic energy equals mass times velocity squared. The consequence of this formula for us is that the faster you go, the more energy you hit the other 'bot with and since our mass is a constant (we can't exceed the weight constraint), increasing the velocity variable is a viable strategy. (Also, because the velocity is squared, it is more important to increase it, rather than the weight.) This will result in a fairly agile 'bot, so care must be taken in not dashing off the edge.

Hitting our opponent as fast as we can (translate to hard with lots of energy) and getting under it while lifting a wheel off the ground is good, but then we have to push it out of the ring. This brings us to the last mechanical strategy and that is torque, often the opposite of speed. The design of the wheel/motor "sub-system" has to be a compromise allowing for a balance of speed and torque, however, there a few motors on the market today which can offer both.

THE DESIGN AND CONSTRUCTION

The rest of this part will be devoted to discussing the actual mechanical design and construction of my Sumo 'bot, illustrated with copious images and photos.

Several of the strategies above involved making sure the robots' wheels have the most friction possible with the surface of the ring, that the bot moves fast when it has to, and at the same time is capable of exerting lots of torque. To satisfy these objectives, I decided to create a "wheel system" by actually building my own wheels from scratch and incorporating a motor inside the wheel. Take a look at Photo 1. This graphic is a CAD representation of the completed wheel system.

THE WHEEL SYSTEM

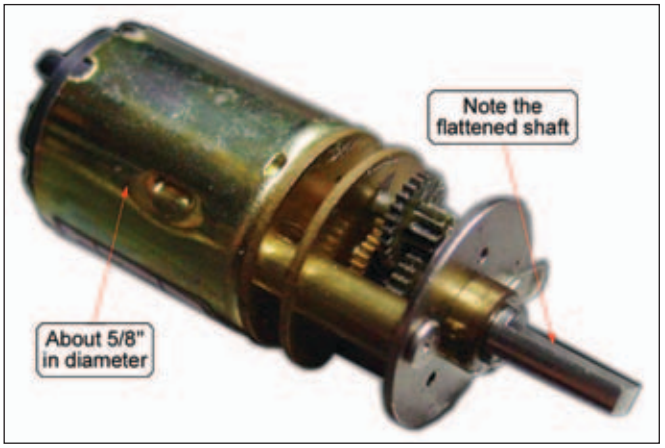
As you can see, this "wheel system" is not a store-bought item, but rather was designed from scratch to present the maximum wheel surface to the ring, to have a sticky surface, and to have incorporated within it (actually inside it) a gear head motor which is capable of providing speed and torque. The wheel system is basically composed of three separate parts: the rim, the motor (which fits almost completely inside the rim), and a molded rubber tire.

The motor I used is made by Copal. It has a gear head built in with a 74:1 ratio and is specified at six volts. The torque rating after gearing is about 43oz/in and, in addition, I overdrove this motor with fully charged LiPols, producing about 8.4 volts.

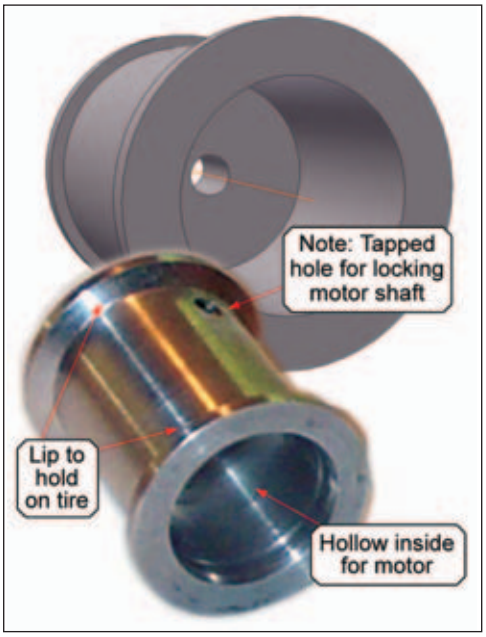
There is a stack of torque here. As an example, a string wrapped around a two-inch diameter wheel on this motor could lift almost four pounds ... our 'bot weighs one pound, so we need the large area and the sticky surface of the wheels we are designing. I also designed the wheel so it had a final diameter such that the 'bot would travel at around 12 inches per second. Note that this means the 'bot will go from one end of the ring to the other in about 2.5 seconds. Lots of speed, but we will also have to be very responsive to the line sensor in order to avoid running out of the ring (see Photo 2).

Other than the motor, two additional components make up the wheel system:

- The rim, which was turned out of an



■ PHOTO 2. Copal gear head motor.



■ PHOTO 3. CAD drawing of the turned rim and finished rim.

aluminum bar.

• A tire, molded over the rim.

The rim was designed to be mostly hollow to allow the motor to fit as far into it as possible; it looks a little like a thread spool which has been hollowed out (see Photo 3).

Now, how do you cast a tire? What do you use for a mold and what substance do you use for the tire itself? Let's tackle the mold first.

THE TIRE MOLD

Just as the rim is custom turned, so are the parts that make up the mold. The mold forms an enclosure around the rim, leaving a vacant area where we want the rubber to be. These are the individual pieces making up the tire mold:

- Two identical end caps.
- The central tube.
- A threaded rod which holds it all together.

For an idea of what the unassembled parts look like, take a look at Photo 4.

Assembly involves putting the threaded rod through the bottom end cap (although you can't see it, the bottom of the bottom end cap is counter sunk to take the head of the threaded rod) and then placing the rim firmly on top of the end cap (see Photo 5). Photo 6 shows the tube in place, ready for the top end cap.

Finally, the top end cap is put in place and the wing nut is tightened down. We don't want any of our casting material to leak past the end caps (see Photo 7).

Okay, the mold is completely assembled and ready for the casting material. Note that on the top end cap, two small holes were drilled: one as input for the casting fluid and the other for the excess to come out. The casting fluid I used is called Por-A-Mold Soft Kit #33508-1308), which I purchased online from **DickBlick.com** The soft version of this is fairly sticky/gooey (good co-efficient of friction), and is very flexible and durable.

I used an empty syringe without the needle to carefully squeeze in a mix of the casting fluid. The syringe was placed in the hole that has the slight counter sink which acted as a locater and gave a better seal. Push the plunger slowly until just a little of the fluid comes out of the other hole, and then set it aside for about six hours. Oh, I forgot, I also purchased Synlube 531 Wax-Based Mold Release Agent with which I sprayed the inside of the tube — do not spray the rim. This, in theory, allows the rim and tube to separate easily, although I had to slide a feeler gauge inside the rim to get it to come apart.

So that's it! Make two of these and you have the wheels ready to accept the Copal motor (see Photo 8).

The next thing to do is to build a "Motor Block" which will hold the motor and wheel and, at the same time, mount firmly onto the chassis base. The wheel block was cut out of aluminum and I had originally intended to cut a slit and have a screw that would tighten it onto the motor. Instead I got lazy, didn't cut the slit, and glued the motor in place. In hindsight, cutting a slit would have been the better mechanical design. Photos 9 and 10 show a CAD drawing of the wheel block and a mock-up of the wheel system mounted to the block.

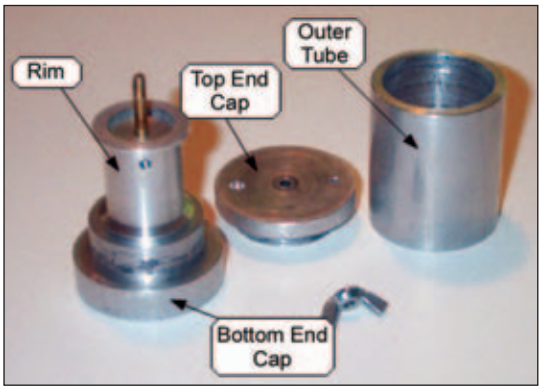
This completes a wheel unit which may be screwed directly onto the chassis base with machine screws. As a "self contained" unit, it may be removed and or replaced as a whole, without affecting the rest of the 'bot.

THE BASE OF THE 'BOT CHASSIS

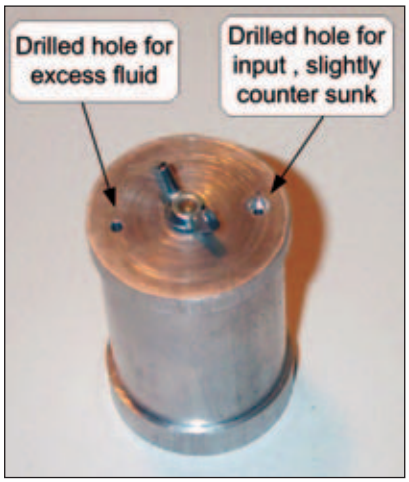
Finally! We get to build the base

■ PHOTO 4. Mold components and rim.

■ PHOTO 5. Mold partially assembled, ready for the tube and top end cap.

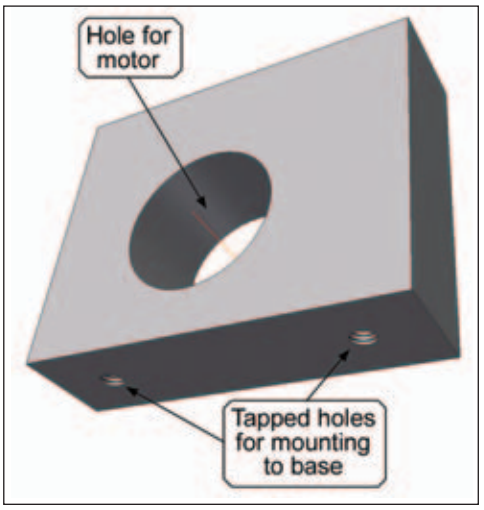


■ PHOTO 6. Mold partially assembled, ready for the end cap.



■ PHOTO 7. Mold completely assembled, ready for the casting solution.

■ PHOTO 8. Completed wheel.



■ PHOTO 9. Motor block.

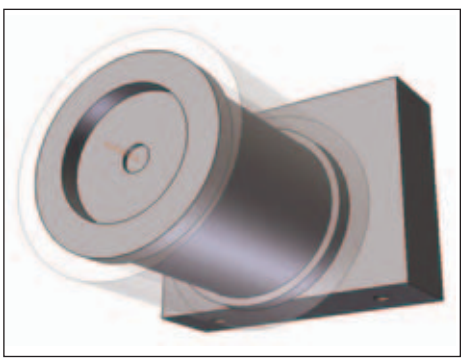
of the chassis. This, of course, is what the wheel blocks will mount to and it will hold the sensors, the electronics, and the batteries, as well.

In keeping with our initial set of strategies, we want to design this so that it is as low to the ring surface as possible to prevent our opponent from getting underneath us. It must also be capable (if possible) of getting underneath our opponent.

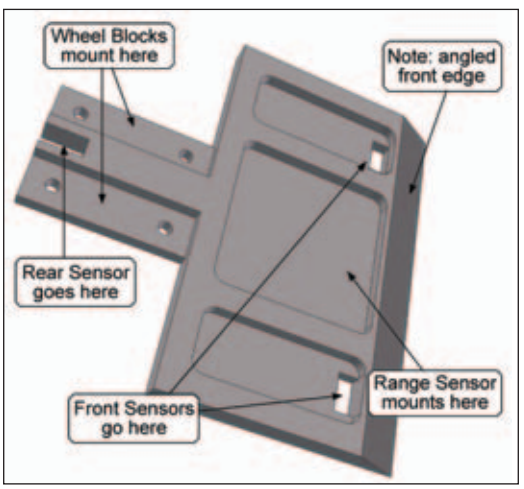
Photo 11 is a CAD drawing of the chassis showing the areas where the wheel block will mount, the slots for the sensors, and — most importantly — the front edge which is angled at about 20 degrees.

As you can see, this front edge presents the opponent with a sharp edge, which will lift his wheels off the surface.

The motor blocks screw onto the base chassis with counter sunk machine screws. The bottom of the chassis must be counter sunk to match. See Photo 12 for a CAD mock-up of the completed 'bot chassis with wheel system.



■ PHOTO 10. Wheel system and motor block.



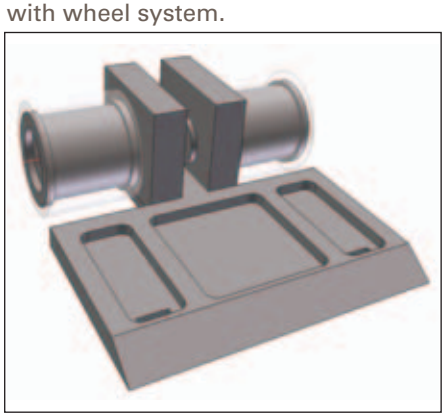
■ PHOTO 11. Base of the chassis.

It's all coming together, so it's time to wrap it up. Hopefully, I've given you a glimpse of what a good Mini Sumo design might be like and what you can do with some patience and perhaps the loan of a friend's machine shop.

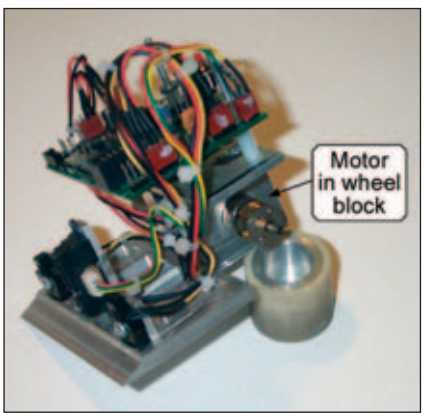
Photos 13 and 14 are the assembled 'bot with sensors and electronics. The space below the electronics board is reserved for the LiPol batteries.

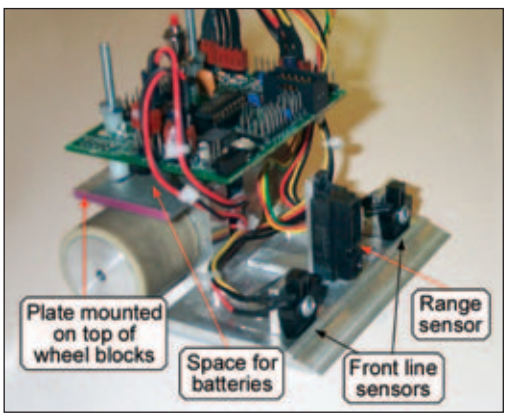
Next month, we will focus on the real-time operating system I used and my program for reading sensors and attacking the opponent. **NV**

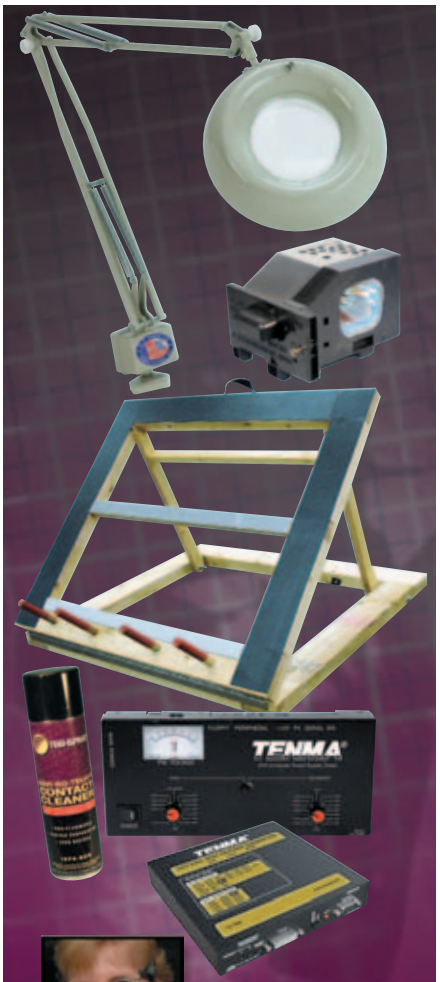
■ PHOTO 12. Completed chassis with wheel system.



■ PHOTOS 13 and 14. Completed 'bot with electronics and sensors.







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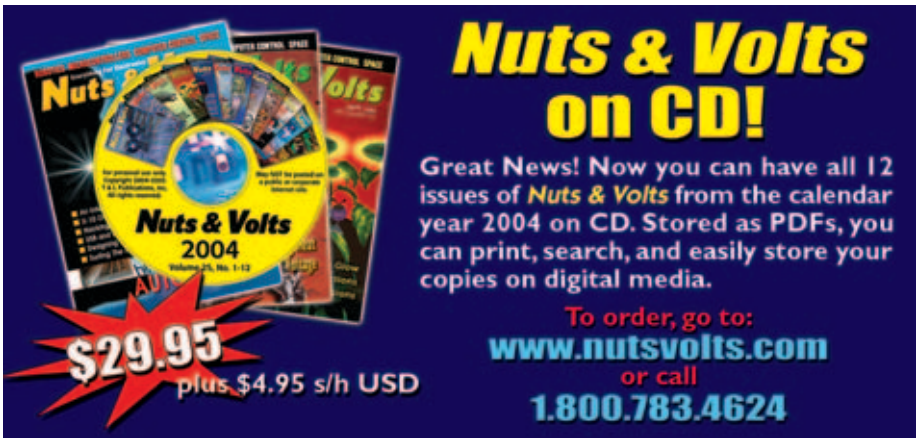

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Different TV systems around the world have historically created video communication problems. A DVD purchased in the US cannot be watched in Europe, or vice-versa. A family may find that all their TV and video equipment is useless when they move to a different country. This incompatibility becomes a major problem for airplanes and ships that move from one country to another.

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- For use with video or TV equipment in a country using different TV systems.

- For use with medical or industrial equipment imported from a country with a different TV system.

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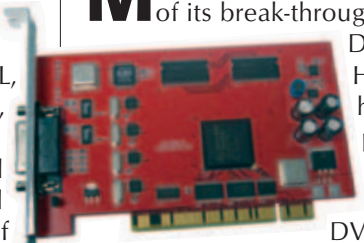
H.264 DSP HARDWARE COMPRESSION DVR CARD



Matco, Inc., announces the release of its break-through technology DVRC-TI Series H.264 DSP hardware compression video capture card. The DVRC-TI series DVR cards apply the most advanced video compression technology for video recording and transmission. The on-board DSP (Digital Signal Processor) compresses the input video signals into H.264 format, which is the latest ISO video compression standard. The H.264 file is only one-third the size of MPEG-4 and it delivers excellent video quality across the entire bandwidth spectrum — from 3G to HD (from 40 Kbps to upwards of 10 Mbps). Since the video signal is processed by hardware, no video processing program is operated by the PC, no PC resource (CPU, RAM) is consumed so that any PC can be used for real-time video recording and real-time remote monitoring for each channel. Different from previous DVR cards, the PC installed with the DVRC-TI series card doesn't need to be dedicated. The DVRC-TI series cards support triplex operation, any chosen channel can operate live viewing, playback, recording, and network accessing simultaneously. Up to four cards can be operated and displayed on the same interface. It provides a watermark function to prevent forgery and provides a low power consumption.

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FROSTED LED TUBE LIGHTS

LEDtronics® announces TBL3xxF Series Sealed Tube LED Light Strips that offer great illumination in many versatile applications. The TBL3xxF series tube LED comes in a milky frosted lens that provides a great looking diffused illumination on applications such as RVs, buses, trains, task lighting, under cabinets, concealed lighting, edge lighting, cubicles, marine recreation applications, retail store displays, and more. The construction of a sturdy UV-resistant polycarbonate housing over the LED tube provides increased protection and shielding against many environmental effects, allowing you to place these light tubes in locations where typical lights would be more vulnerable to the elements. Furthermore, TBL3xxF series tubes come in a variety of lengths (6", 12", 24", and 48") to fit in many different locations, tight enclosures, and spaces.

These frosted LED tube lights come in 6000K Pure White and 3000K Warm

White colors all operating at 12V. Both whites use .96 watts for the 6″ model, 2.16 watts for 12″, 3.84 watts for 24″, and 7.68 watts for 48″ lengths. Pure white 6000K LEDs give off 52 lumens at 6″ lengths, 116 lumens at 12″, 206 lumens at 24″, and 413 lumens at 48″ sizes. Warm White 3000K LEDs radiate 40 lumens for 6″, 89 lumens at 12″, 158 lumens at 24″, and 317 lumens at 48″ length sizes. Other varieties of LED colors are available for OEM customers.

Along with each LED tube strip is a mounting clip (MTG-CLIP-STP-001) that snaps onto the back of the tube. Two clips are provided per foot of tubing. Each clip has a location for a self tapping screw that allows users to mount the LED tubing in different locations.

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Prices for TBL3xxF series sealed tube LED lights retail from $26.95 to $108.35, depending on length. Large quantity discounts are available. Availability is stock to 4-6 weeks for special requirements. TBL3xxF LEDs carry a three-year limited warranty.

For more information, contact:
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Torrance, CA 90505
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310-534-1505
Fax: **310-534-1424**
Email: **webmaster@ledtronics.com**
Web: **www.ledtronics.com**

DELUXE DUAL DISPLAY, 51,000 COUNT DMM

B&K Precision Corporation's new Model 2890A Deluxe Dual Display, 51,000 Count DMM is the latest addition to its growing line of test and measurement instruments. The new hand-held, battery powered DMM offers true RMS ACV and ACA, in addition to many features that are useful for troubleshooting complex electrical and electronic circuits. The Model 2890A can also be used to test and evaluate circuits in a field service application. The Model 2890A is the ideal tool to get the job done quickly and economically, and is a must for every tool kit.

The Model 2890A's features include true RMS ACV and ACA, AC+DC true RMS, five digit LCD for both primary and secondary displays, 21 segment analog bar graph, automatic polarity indicator, 0.025% basic DCV accuracy, resistance measurements up to 500 MΩ, conductance measurements up to 50 nS with 0.01 nS resolution, capacitance measurement, frequency with ACV measurement, data hold, dBm measurement, REL mode, 1 ms peak hold for glitch capture, back lit LCD, frequency counter up to 20 MHz, squarewave output with 28 frequency ranges and adjustable duty cycle, conforms to IEC-1010-1 600V CAT IV and 1000V CAT III, and it is CE approved.

The new Deluxe Dual Display 51,000 Count DMM offers versatility and reliability for a broad spectrum of bench-top and field applications. In addition to the unit's two backlit five-digit LCD readouts that can display both ACV and frequency simultaneously, the meter can be used to measure DCV, ACV, DCA, ACA, OHM, diode check, audible continuity, temperature, frequency, duty cycle, and pulse width.

Compact (7.56″ x 3.55″ x 1.46″) (192 x 90 x 37 mm), and light weight (2 lbs) (936 g), the unit is available for immediate delivery. It is priced at $305, and comes complete with 9V battery, test leads, carrying holster, and manual. A complete line of optional accessories is also available.

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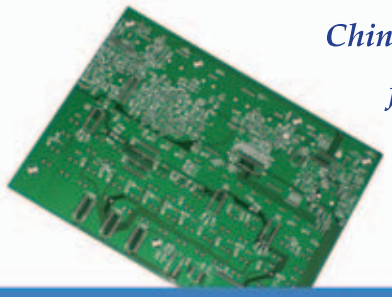

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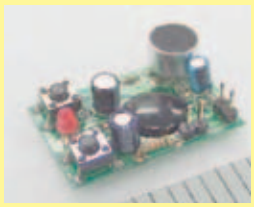

20 second voice recorder/playback module. The electret microphone is on the board. One button to record, the other button just has to be momentarily pressed to replay the message. (pre-assembled) **$6.60**

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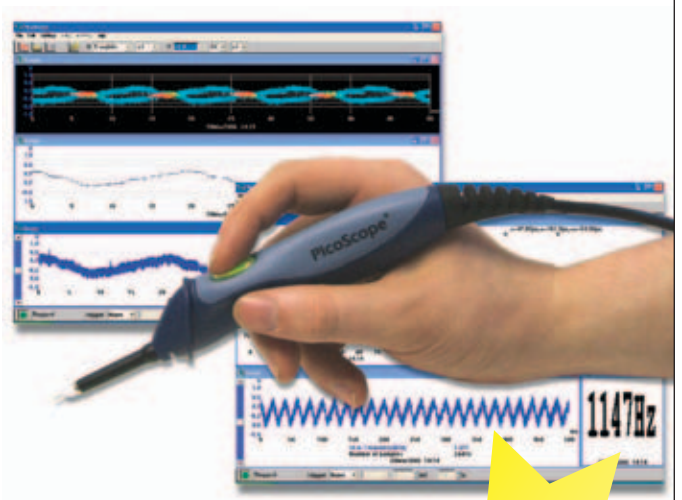

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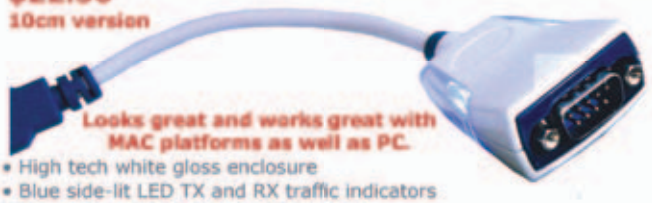

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10cm version

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THIS MONTH'S PROJECTS

Stereo Microphones 36
Control Your World — Part 2 . . .40
The TrainSaver 46

LEVEL RATING SYSTEM

To find out the level of difficulty for each of these projects, turn to our ratings for the answers.

●○○○ . . . . Beginner Level

●●○○ . . . . Intermediate Level

●●●○ . . . . Advanced Level

●●●● . . . . Professional Level

Friends, birders, electronics enthusiasts, lend me your ears so that you may listen to faraway sounds using these easily built long-range stereo microphones.

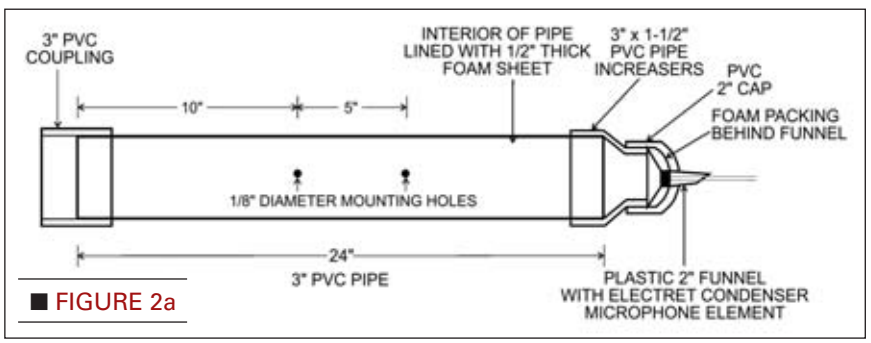
(with apologies to William Shakespeare and Mark Anthony)

LONG-RANGE STEREO MICROPHONES

A readily available Velleman "Super Stereo Ear" Mini Kit, or manufactured "for the hard of hearing," microphone/amplifier assemblies, plus some PVC tubing, foam inserts, a few pieces of wood, and a handful of nuts, bolts, and volts is all that is needed to build a stereo microphone system that lets you pick up distant acoustic signals with clarity and accuracy.

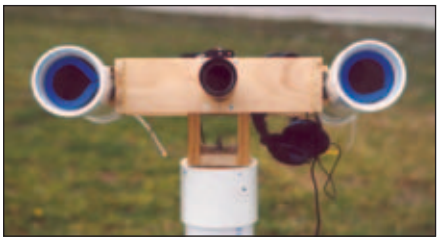
Using electronics to listen in on birdcalls or other distant sounds is not a new undertaking. I used the guidelines given by Charles D. Rakes in his December 2002 *Poptronics* article, "An Ear to the Outside World" (pp. 55-58), to construct the long-range microphones presented in this article but with one big difference — my design incorporates a dual microphone system so that the listener can hear in stereo. I find that using two microphone/amplifier systems (one for each ear) placed at spacings of two to three times the normal ear-to-ear

■ FIGURE 1. Three views of "Big Mike" showing the arrangement for the two 24-inch microphones fastened about 18 inches apart on a simple altazimuth mount. The center tube is an optional Galilean telescope.

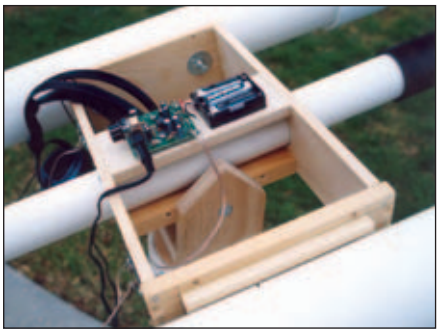


■ FIGURE 2a

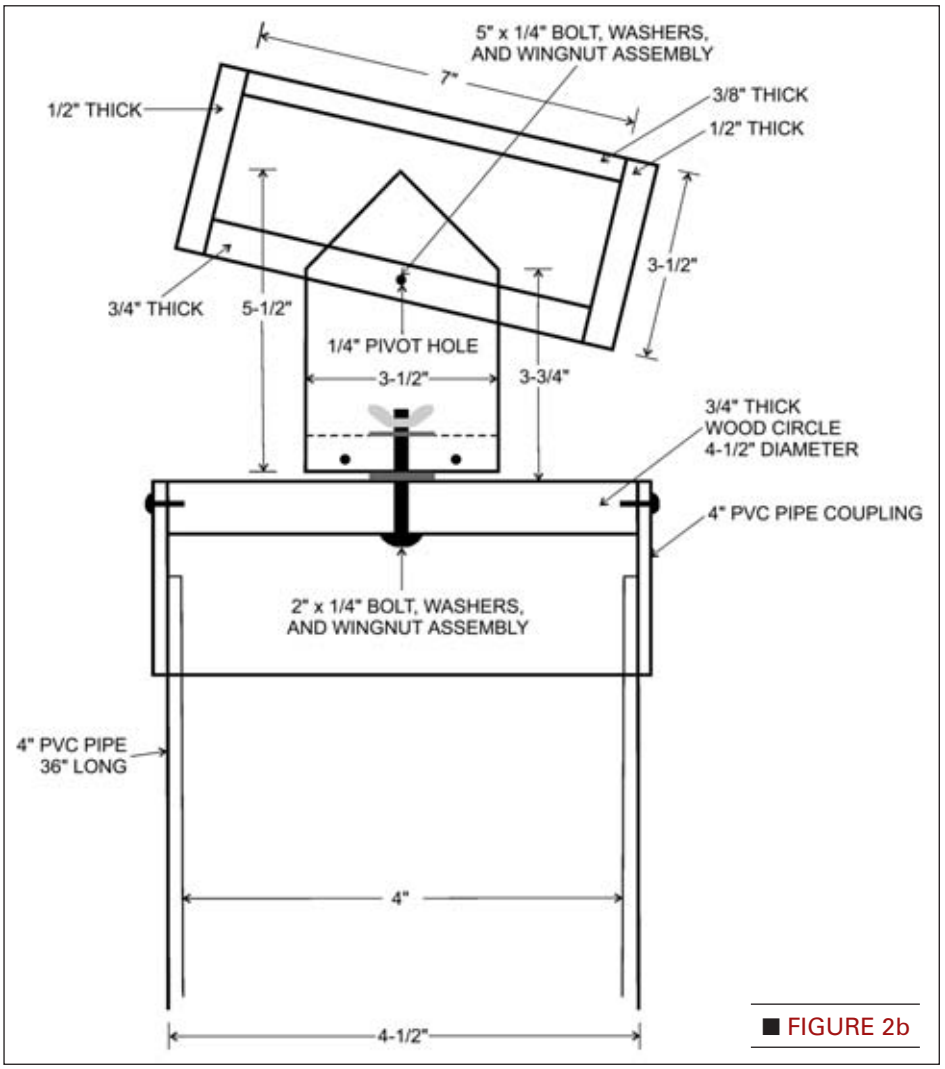
■ FIGURE 2. Construction details and dimensions for the microphone tubes and mount: (a) Microphone tube; (b) Interior section of the altazimuth mount; and (c) Front of altazimuth mount.



■ FIGURE 3. Front view of the microphone tubes showing the plastic foam inserts (blue) used as sound dampening material.

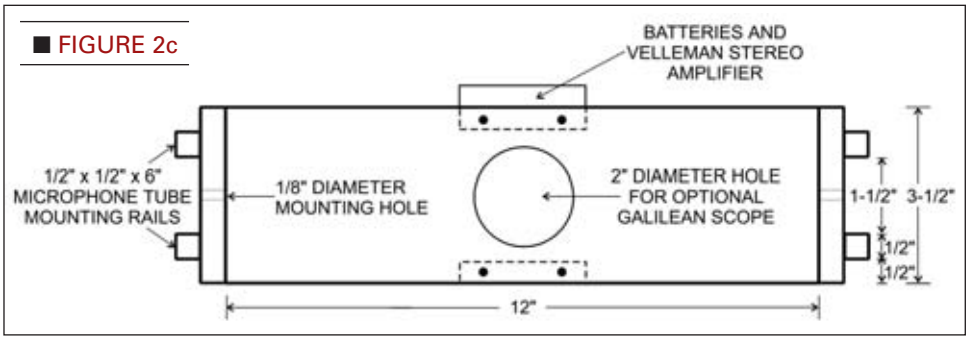


■ FIGURE 4. Placement of the battery holder for three AA batteries and of the Velleman "Super Stereo Ear" printed circuit board is visible, along with a close-up look at the altazimuth mount construction.



■ FIGURE 2b

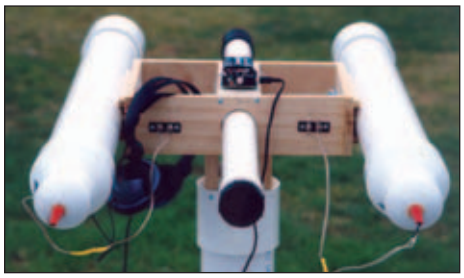
■ FIGURE 2c



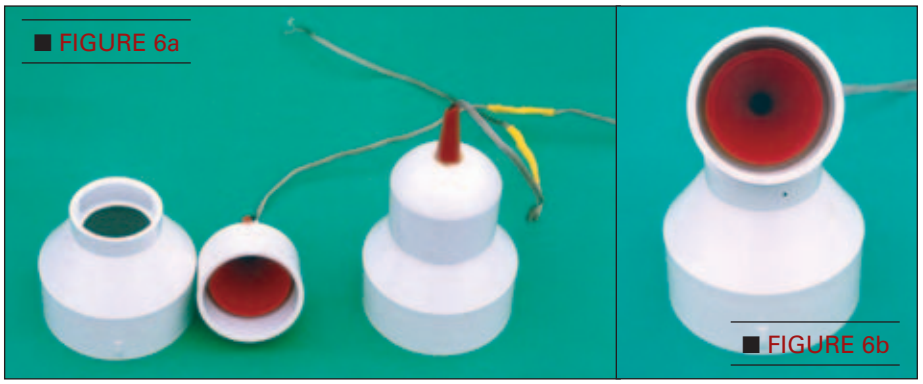
distance (about 6-7 inches for an adult) enhances the listening experience in terms of sensitivity to nearly inaudible sounds and sensitivity to direction. I constructed two systems. One system, which I call "Big Mike" (see Figure 1), follows more closely the instructions given by Rakes for creating a mono, long-distance mic. Figures 2a, 2b, and 2c show the details for constructing "Big Mike." I had a hard time finding thin sheets of foam rubber to act as sound insulating material and instead cut up a plastic foam camping mattress that was about half an inch thick (see Figure 3).

The microphones are sensitive electret elements that are part of the Velleman kit MK136 "Super Stereo Ear," which is ideal for this project. Figure 4 shows the placement of the stereo amplifier and the battery holder on top of the wood mounting platform. Figure 5 shows where the electret microphone elements — glued inside orange plastic funnels — are located in order to channel the sound at the end of each tube. Close-ups showing details of the microphone element-to-funnel assemblies are shown in Figure 6.

The two 3 x 24 inch PVC tubes with insulating foam and end caps weigh about 10 lbs. I found it necessary to attach them to a crude (but effective!) wood altazimuth mount



■ FIGURE 5. Back of the microphone tubes showing the hookup wires for the electret elements exiting the orange funnel stems sticking through the two inch PVC end caps. Gorilla Glue was used to glue the funnels in place and Goop was used to glue the two-inch PVC end caps to the 3 x 1-1/2 inch PVC pipe increasers.



■ FIGURE 6. Close-up views of the funnel/microphone/end cap assemblies. (a) Left end-cap unassembled; right end-cap in final configuration. (b) Close-up of funnel in end-cap; the electret element has been glued into place about 1/2 inch down the exit throat of the funnel stem.

"BIG MIKE" PARTS LIST

QTY	ITEM/DESCRIPTION
❑ 2	24 x 3 inch PVC pipes
❑ 2	3-inch PVC hub-to-hub couplings
❑ 2	3 x 1-1/2 inch PVC hub-to-hub pipe increasers
❑ 2	Two-inch PVC soc caps
❑ 2	Two-inch diameter funnels from set obtained at American Science & Surplus (**www.sciplus.com**), part number 91078 (You will need to order two sets of four funnels to get the two funnels you need — these are hard to find and this set is inexpensive @ $1.75 per set.)
❑ 2	1/2 x 24 x 8 inch pieces of foam camping mattress pad or any other similar material suitable for sound dampening
❑ 1	36 x 4 inch PVC pipe (pier)
❑ 1	Four-inch PVC hub x hub coupling (pier)
❑ 1	Four-inch PVC hub closet flange (for base of pier)
❑ 1	Velleman MK136 "Super Stereo Ear" mini kit ("boosts sound 50 times")
❑ 1	Stereo headphone

Miscellaneous wood boards, hardware, and glue

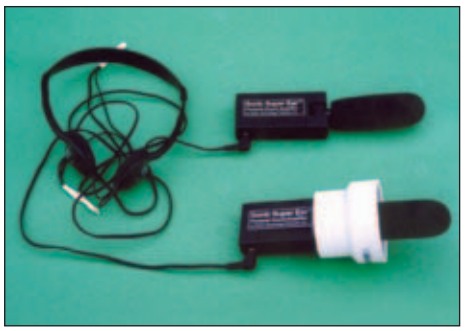
(see Figure 4) using four-inch PVC pipe as a pier. The optical telescope in the middle between the two mics is not necessary, but if you are looking for an excuse to make and use a Galilean telescope (which provides a correct, right-side-up view), this is a reasonable construction opportunity. The catalog from Anchor Optical Surplus (**www.anchoroptical.com**) has instructions for building a Galilean telescope with lenses you can order from them.

A second, smaller system, based on the same principles as Big Mike, was constructed as a handheld unit (Little Mike) and is shown in Figure 7. This project makes use of readily available components and a small wooden mount that requires only a little cutting and gluing. The two microphone/amplifier assemblies (see Figure 8) are the type you find in household gadget catalogs with names that include "Sonic" and "Super Ear." They work quite well, but the earphones accompanying them are wired for mono listening with the single microphone/amplifier.

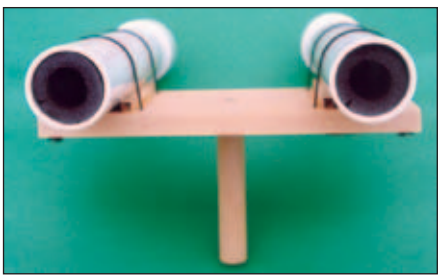
A little cutting and soldering will allow you to connect the left earphone to one microphone/amplifier and connect the right earphone from the same headset to the other microphone/amplifier so you can listen in stereo. And yes,

■ FIGURE 7. Photo of "Little Mike" constructed from two 13-inch long, two-inch diameter PVC microphone tubes mounted nine inches apart on a 12 x 5-1/2 x 3/4 inch wooden platform using 1/4 x 1/4 inch mounting rails and cable ties.

■ FIGURE 8. Pair of "Sonic Super Ears" used for the microphone/amplifier systems. The plastic case of one of the microphone/amplifier systems is shown cemented into a 2 x 1-1/2 inch PVC pipe increaser using Gorilla Glue.



■ FIGURE 9. Rear view of "Little Mike," showing the two-inch outside diameter polyethylene foam pipe insulation inside the PVC tubes. The microphones with foam covers (see Figure 8) fit nicely into the 1-1/4 inch inside diameter core of the polyethylene foam pipe insulation inserts.



since you bought two complete microphone/amplifier systems, you have one headset left over — think of it as a spare.

The two PVC pipes used to house the microphones are, fortuitously, slightly greater than two inches inside diameter and will nicely accommodate the polyethylene foam-pipe insulating material that is two inches outside diameter (see Figure 9). This makes for easy construction; simply cut off an appropriate length of the two-inch PVC pipe (you can try longer lengths than the 13-inch length I used with perhaps better results) and then cut off the same length of the polyethylene foam-pipe insulation and insert it into the PVC tube.

The microphones, which have their own black foam cover, fit exactly into the inside diameter of the polyethylene foam insulating tube. I used 2 x 1-1/2 inch PVC pipe increasers as end pieces so I could glue the amplifier housings onto them to make rigid assemblies that could be placed at the end of the PVC pipes. I did not glue the microphone/amplifier/pipe increaser units to the end of the PVC pipes, but simply used a press fit, which turned out to be very snug and won't come apart unless you tap them lightly with a small hammer.

I used a 12 x 5-1/2 x 3/4 inch wooden platform and plastic cable ties to fasten the PVC microphone/amplifier assemblies nine inches apart. A six-inch long, one-inch-diameter dowel attached to the underside of the wooden platform acts as a handle. This system, although much lighter than Big Mike, weighs about 3-1/2 lbs. and can be tedious to hold for long periods of time. A four-foot by one-inch PVC pipe, with a 1-1/4-inch rubber chair tip to act as a foot at one end, can be used as a monopod — just slip the one-inch-diameter dowel handle into the pipe opening (the dowel handle visible in Figure 9 is shown mounted in the monopod pipe in Figure 10), and you can effortlessly aim the microphones anywhere you want.

Both setups work well and have advantages and disadvantages. There are obvious differences in transporting ease and handling ability, due to size and weight. Big Mike is more sensitive to direction but is also noisier. Little Mike has two separate amplifiers with separate volume controls, which may be useful if you are more hard of hearing in one ear compared to the other, but it does take a few seconds to balance the sounds. In any case, they are certainly fun to use, and they do attract a crowd! **NV**

■ FIGURE 10. Rear view of "Little Mike" with microphone/amplifier/PVC pipe increaser assemblies attached to the PVC tubes.

"LITTLE MIKE" PARTS LIST

QTY	ITEM/DESCRIPTION
❑ 2	13 x 2 inch PVC pipes
❑ 2	Two-inch PVC hub-to-hub couplings
❑ 2	2 x 1-1/2 inch PVC hub-to-hub pipe increasers
❑ 2	13 x 2 inch diameter polyethylene foam pipe insulation jackets for steel and copper pipes (You will need to measure the outside diameter and inside diameter of this material at the hardware store — depending on the brand, they can vary considerably in size even though they are meant for fitting the same size pipe.)
❑ 2	Microphone/amplifier systems that go by the trade name of Sonic Super Ear (A search on the Internet using the trade name will produce a number of sites — check out all sites as prices vary considerably.)
❑ 1	48 x 1 inch PVC pipe (for monopod)
❑ 1	1-1/4 inch rubber chair tip (for monopod)
Miscellaneous wood boards, hardware, and glue	

CONTROL YOUR WORLD

PART 2 — Interface Your PC to the CMUcam

A while back, I was researching sensors for a project I was working on when I came across a little device called a CMUcam.

The CMUcam is a low-cost vision sensor developed by Carnegie Mellon University (www.cmu.edu).

The CMUcam has both an RS232 level interface, as well as a TTL level serial interface so you can connect it to your favorite microcontroller or directly to a PC.

There are two versions of the CMUcam being sold now: the original CMUcam and the CMU2cam2. I will concentrate on the lower-priced CMUcam, but with slight modifications, the code presented here will work with both cameras. The CMUcam has a resolution of 80 x 143 pixels. This low resolution may not be perfect for creating web pictures, but it works great for an image sensor with an RS232 interface.

Where Can I Get a CMUcam?

You can't get a CMUcam from Carnegie Mellon directly; you must purchase it from a licensed manufacturer/distributor.

The CMUcam fully-assembled can be purchased from Images SI, Inc., at **www.imagesco.com** This camera comes with a small cable and will cost you about $109.

The CMUcam2 camera comes in a couple of variations, which can be purchased from Acroname at **www.acroname.com** The camera I interfaced was a CMUcam2+, and does not include a RS232 level converter. The camera and level converter will run you about $181.

None of the cameras come with a printed manual. You will have to download the latest manual from the web. The manual will have all the connections and jumpers for the camera, as well as a list of all the interface commands. The CMUcam2+ comes with a hookup sheet since it has a different hardware layout than the CMUcam2.

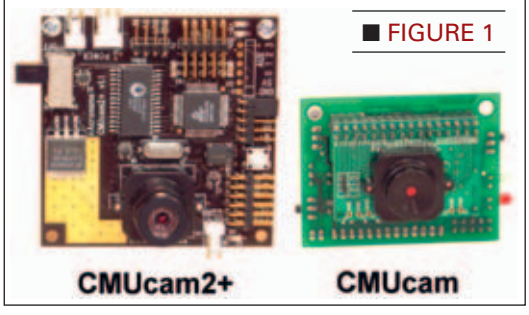
The Interface

The camera I purchased

ZEUS

■ This article uses a Basic programming language called Zeus. Zeus is a simple Windows programming environment that specializes in interface design. A special *Nuts & Volts* version of the software is available free, along with the application and source downloads on the *Nuts & Volts* website (**www.nuts-volts.com**). A couple compiled applications are also provided for those who don't want to play with the code.

This article will not present the actual source code for space considerations. The actual source code is included in the download and has plenty of comments that explain the sections where appropriate.



■ FIGURE 1

came with a very small RS232 cable, so you will need a nine-pin male to female straight-through cable to connect your PC. The camera has jumpers to set the baud rate to 9600, 19200, 38400, and 115200. All the programs used here have the 115200 rate, so set the jumpers accordingly. If you have a slow machine, you may want to use one of the slower baud rates. The camera requires six to nine volts DC to run. There is a single two-pin header used to connect your power source. I soldered a 2.1 power coax connector to a two-pin female header so I could use an AC adapter. (*Tip: I took a standard 2.1 coax and soldered it to the two power terminals, as shown in Figure 2. This can be done on both the CMUcam and the CMUcam2+.*) You can also use a nine-volt battery, but you will have to make the connector.

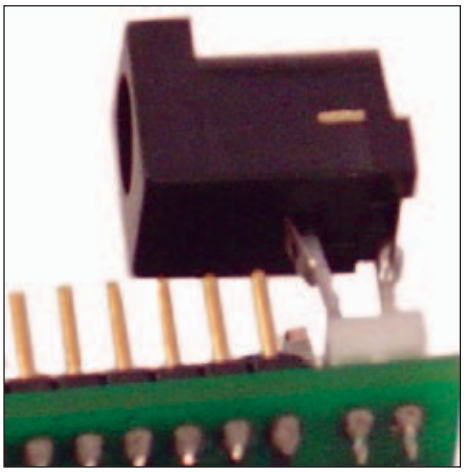
To get started, let's look at the DF command. This command tells the camera to dump a single frame of data. This will help us focus the camera and is one of those instant gratification things we geeks like to see when we purchase something new.

The DF command dumps a complete frame (80 x 143 image) of data in the form of 1 2 r g b r g b r g b ... 2 r g b r g b ... 3

where:
1 = Frame Start
2 = New Column
3 = Frame End
r = Red value 16-240
g = Green value 16-20
b = Blue value 16-240

Start by loading the program called CMUProgram1.txt and then run it. If you have the correct comport set, you should see the image start to display column-by-column until it is built.

Figure 3 shows a typical capture. Did you notice the flicker as the image was being drawn? This is typical when you are building a graphic image as we are. One way to create a smooth and clean image is by using a method called double buffering. The free version of ZeusDeskTopNV v1.50 has two commands that support double buffering. They are FormUpdateAutoOff and FormUpdate. The FormUpdateAutoOff turns the automatic update system off and the FormUpdate command lets us update the form manually.



■ FIGURE 2

Load and run CMUProgram2.txt. This program uses the new commands and updates the form as each column completes. This program also continuously dumps the frame. Notice the difference? In many cases, you can't even tell the image is updating unless the image itself changes.

You may have noticed that the actual display resolution was 160 x 143 not 80 x 143, as stated earlier. The column pixels are doubled to correct the aspect ratio during display.

Turn it Up

As a practical example, let's look at a security application. We can point the camera at an item or entrance to scan for a change in pixels. The problem is that it takes nearly five seconds to pull in the image using the DF command.

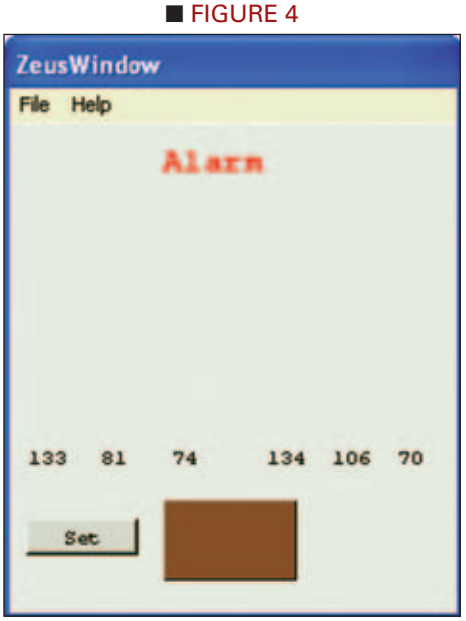
The CMUcam has several built-in commands that let the camera actually analyze much of the data for us. One command is called the GM command, which stands for "Get Mean." This command constantly dumps six values: Red Color Average, Green Color Average, Blue Color Average, Red Deviation, Green Deviation, and Blue Deviation.

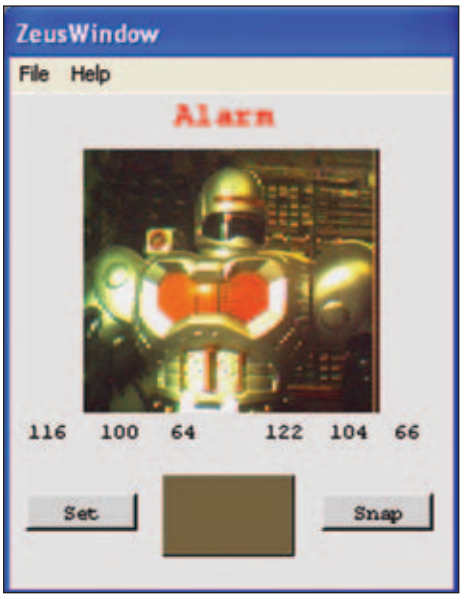
■ FIGURE 3

For our security application, we will use the first three. The cool thing here is that we get several readings per second so our program can be very responsive.

Load and run CMUProgram3.txt. I have included a wave file called Bell.wav. Place it into the same directory as the program code. After a few seconds, the average readings will be stored into variables and, if there is a deviation of more than 20 units in any one color, it will trigger an alarm. The

■ FIGURE 4





■ FIGURE 5

output should look like the form in Figure 4.

Going Further

Okay, so we can trigger an alarm; let's take a look at CMUProgram4.txt. Here, we made a few slight modifications to the ProcAlarm function. The function now returns 1 when an alarm is triggered and 0 if not.

We also added a function called SnapShot that dumps a frame on to the form when the alarm is triggered. Figure 5 shows such a dump after I turned on a light that caused the alarm to trigger.

You could also modify the ProcAlarm function to return different codes based on which color actually tripped the alarm.

Read the CMUcam manual and take a look at the many other commands. The camera has a servo connector and commands to control it. You can even set up the camera to track objects.

The CMUcam2+

There are command differences between the CMUcam and the CMUcam2. I have included three CMUcam2 program files that will work on a CMUcam2 or CMUcam2+.

I thought it important to describe a few of the differences between the CMUcam and the CMUcam2+. The CMUcam2+ has two resolutions. The lower resolution is 87 x 143 and the higher resolution is effectively 175 x 254, regardless as to what the manual states.

The CMUcam2+ buffers the internal images so that when dumped, it will not blur. There are also several more tracking commands for automated tracking, as well as feedback to determine the direction the object is moving.

The CMUcam2+ supports five servos and four I/O ports. The camera also has a sleep mode to conserve power. The CMUcam has only a single servo hookup. The CMUcam2+ is also much faster than the CMUcam and outputs a better quality picture in poor lighting.

The downside to the CMUcam2+ is that if you want to control the camera with a PC or Pocket PC, you will need a RS232 level shifter.

Which is better? It all comes down to how much you want to spend. Other than the RS232 level shifter, the CMUcam2 will do everything the CMU2cam will do, but it costs nearly $80 more and has a bigger footprint.

I have included two CMUcam2 source files. They are called CMU2 LowResDump.txt and CMU2HighRes Dump.txt. This will get you started with the CMUcam2 if you decide to go that route.

As a bonus, I created three applications with ZeusPro. The first is a fancy version of the CMUcam alarm program for the CMUcam2. This program will dump the image that triggered the alarm to disk in the form of a 350 x 255 jpeg.

The other two programs are small web servers that will dump an image every 60 seconds and serve it up over the Web if requested by a browser. Not to leave anyone out, I created both CMUcam and CMUcam2 versions.

It is already built for you. The applications, as well as the source can be found on the KRMicros website at **www.krmicros.com/Development/ZeusPro/ZeusPro.htm**

What Else Can You Do?

The CMUcam has one servo connector and the CMUcam+ has five. By mounting the camera to one or more servos, you can utilize some of the built-in auto tracking features or, at the very least, use Zeus to pan and tilt the camera.

Experiment and have fun, and be sure to visit the "Control Your World" forum at **www.kronosrobotics.com/forums/viewforum.php?f=21** NV

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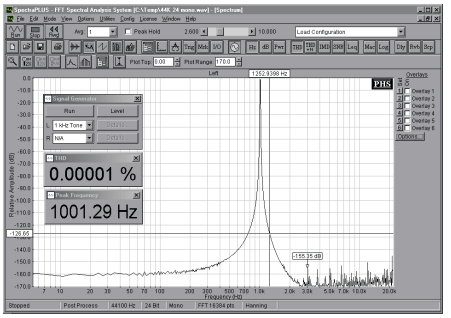

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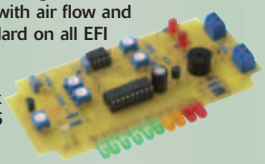

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- Requires 12VDC power
- Recommended box UB5 HB-6015 $1.40

NEW FOR '06

Three Stage FM Transmitter

KJ-8750 $12.75 + post & packing

The circuit board may measure just 2 3/4"(L) x 2/3"(W), but it can transmit signals over half a mile in the open. It has flexible power requirements, with 6 to 12VDC input voltage (a 9V battery would be suitable). It is quick to build, and fun to use. Kit supplied with circuit board, electronic components, and clear English instructions.

- Recommended box UB5 HB-6015 $1.40

Tempmaster Kit

NEW FOR '06

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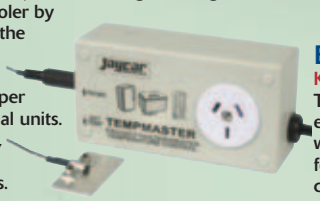


Australian to US mains adaptor required. Use PP-4020 $5.50

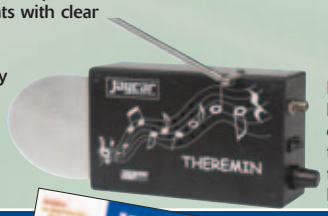
Theremin Synthesizer Kit

KC-5295 $34.95 + post & packing

The Theremin is a strange musical instrument that was invented early last century but is still used today. The Beach Boys' classic hit "Good Vibrations" featured a Theremin. By moving your hand between the antenna and the metal plate, you can create unusual sound effects. Kit includes a machined, silkscreened, and pre-drilled case, circuit board, all electronic components with clear English instructions.

- This product is also available built and fully tested AM-4025 $64.95

Requires 9VDC wall adaptor (Jameco #252751 $12.05).



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- Requires 9-12VDC power

For all you Trekkie fans

Battery Zapper MkII

KC-5427 $58.00 + post & packing

The circuit produces short bursts of high level energy to reverse the damaging sulphation effect in wet lead acid cell batteries. This improved unit features a battery health checker with LED indicator, circuit protection against badly sulphated batteries, test points for a DMM and connection for a battery charger. Kit includes machined case with screenprinted lid, PCB with overlay and all electronic components with clear English instructions.

- Suitable for 6, 12, and 24V batteries.
- Requires 9-12VDC power

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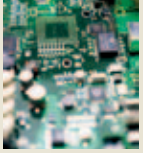

The TrainSaver is a device that reduces wear and tear on model train locomotives used in commercial environments.

THE TRAINSAVER DIGITAL ELECTRONIC TRAIN CONTROLLER

The TrainSaver maximizes the life of the engine by only running the train on timed intervals, and only when people are present to view the train's performance. This reduces the cost of ownership of the train system by increasing the life of the engine. The device also adds synchronized sound effects to enhance the train's visibility to the audience.

It All Started With a Hankerin' for Bar-B-Que ...

The PokeJo's BBQ restaurant that my fellow workers and I frequent here in North Austin, TX, has a nifty electric train that circumnavigates the entire restaurant. As we entered the establishment one afternoon, we noticed the train was missing! A short chat with the manager revealed the train would break down from continuous use and had to be sent to a repair shop. Moreover, the cost of repairing the train engines had gotten high enough that the management had canceled plans to add trains to any of their other locations and was even considering retiring the existing train from our favorite restaurant!

I began to mull over the problem and decided I should be able to rescue the train from abandonment while maybe at the same time enhancing its value to the restaurant. A few inquiries with a local hobby shop showed there might also be other applications for such a solution in enhancing the life of other toy trains used in commercial environments. It seems that the motor and gear train in many consumer grade trains are not designed for the continuous use to which they are put when placed in a commercial venue. Since there are a limited number of hours their gearboxes and motors could provide, we needed to find a way to get the most out of them.

Is it Train Time Yet?

Initially, my design revolved around various timer circuits to reduce the total amount of time the train spent in a powered condition (presumption being less run time = longer life). I built a simple 555 timer circuit to start and stop

Acknowledgements

■ I would like to thank the following people who were critical in making the TrainSaver a reality: Jim Huggans, Sharon Sudduth, Nic Graner, Paul Atkinson, Denise Scioli, The Robot Group of Austin, and the good folks at the PokeJo's BBQ restaurant.

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the train on intervals, but on testing, I discovered this approach was less than adequate. With no positioning feedback, the train would stop at random points around the track when power was removed by the timer. It was also not very realistic as it seemed as if the train had malfunctioned when it would stop or start for no apparent reason in mid-lap around the track.

Some patrons actually approached the cashier to point out that the train had broken down. Worse yet, my simple timer approach would not allow the staff to start the train on demand for folks who would ask to see it run (as a treat for someone's birthday, for example).

Having the train run and stop in a predictable manner, combined with the ability to start the train on command, would seem to need something more sophisticated than a simple timer. In fact, it seemed to call for a microcontroller. Coincidentally, it would also give me an excellent opportunity to create a project around the new Prop-1 I had purchased (see Figure 1) from ParallaxEFX — a new division of Parallax that specializes in controllers for animatronics and entertainment devices. The Prop-1 microcontroller seemed to be a good match for this project for the following reasons:

- It is low cost at only $35 for the complete, assembled unit.

- It has an on-board ULN2803a high-current Darlington chip capable of driving inductive loads.

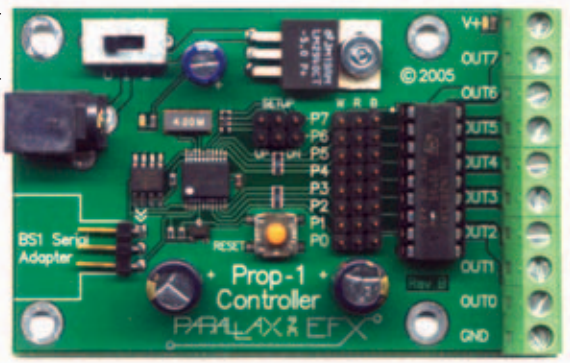
- The ULN2803a is socketed so this critical part would be field replaceable.

- With eight I/O pins, it has plenty of device control available.

- Using PBASIC, it's easy to program.

Of course, once we have a microcontroller at our command, we have a slew of new capabilities that can add fun and value to the project. For example, we could utilize Pulse Width Modulation (PWM) to gently start/stop the motor. This should enhance the life of the motor and the gear train since it would reduce the instant torque exerted on the gear box when power was applied/removed. It would also make it trivial to allow direct control of the train so the restaurant staff could trigger it to perform on command.

■ FIGURE 1. The Prop-1 from ParallaxEFX.



With a microcontroller, I could add a position sensor to have predictable stop and start points and also count the laps the train had run. At first, I imagined using Hall-effect sensors or some other physical method to sense the train's position, but it seemed simpler and possibly more reliable to use a touch free sensor. I decided that an IR LED/IR phototransistor arranged in a beam-break style would provide a good way to determine the train position without requiring any modifications to the train or the track.

Also, most train track setups have a station, trestle, tunnel, or some other feature where the IR LED and sensor could be mounted, so this seemed the best approach. In our case, there was an obvious section of the track where the train should stop, so the optimal position for the sensor was easy to determine (there is a tunnel that would hide the train from view).

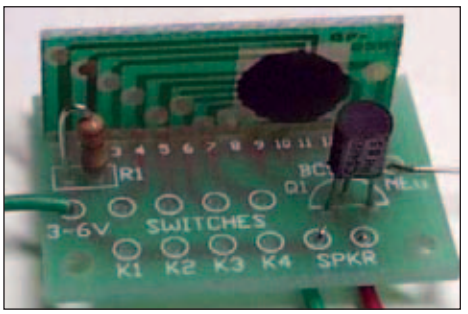
Since the train would be integral to the ambiance of the establishment, we could have a self-start mode that would cause the train to run one or more laps if it was left idle for a software configurable period of time (i.e., not manually triggered by an employee in a 10-minute period). Since the idea was to have the train operate without attention from the staff, the user interface should be as simple as possible consisting entirely of a single button and a single indicator LED. So I had my list of requirements ... or did I?

What's a Train Without a Whistle?

I tried out my prototype design at the restaurant, and I was able to have the train run on command, run on unattended intervals, and stop and start from a consistent location. I even had a small PWM routine in the code that would ramp the power up on start and down on stop to ease the strain on the motor/drive train. However, as I observed my prototype design in action, I noticed that in many cases people would not notice the train had started, or were puzzled when the train would just disappear without apparent reason.

It occurred to me that having some sort of sound effect would add to the realism of the train and bring people's attention to it when it was

■ FIGURE 2. The Chip On Board (COB) Train sound effects sound module fully assembled.



■ FIGURE 3. Train Sound Effects Kit components.

about to perform. For variety, I could use specific sounds to indicate when the train was stopping or just passing through the station. Since the Prop-1 had some unused outputs in my existing design, I decided to look for a sound module.

Sound, Sound, Everywhere the Sound

A quick web search turned up a very inexpensive COB (Chip On a Board) digital sound generator (see Figure 2). This little sound module kit is widely available from various manufacturers online. The Train Sound Module Kit comes with the sound generator itself, four NO (normally open) pushbutton switches, a small motherboard on which the chip is mounted, and a 3", eight-ohm speaker (see Figure 3).

This neat little module plays back digital samples of various train sound effects including a crossing bell, the clickety-clack of the train wheels on a trestle, and a steam train whistle. Due to the nature of the switch inputs, it would be trivial to trigger the sounds using pins on the Prop-1. Since I can establish the position of the train using the IR beam-break sensor, I would be able to trigger the various sound effects to occur when the train was near the speaker, thus enhancing the illusion the sounds were emanating from the train itself.

■ FIGURE 4. Eight watt audio amplifier kit.

Whistle With Laryngitis?

After I assembled the COB sound module, I noticed it came with a rudimentary audio amp in the form of a single transistor output. On my bench the sound was audible, but certainly didn't play with much authority. When I put the prototype in place at the restaurant, you couldn't hear the module at all! The single output transistor on the module just wasn't putting out enough power.

I decided to beef it up by ordering an eight watt audio amplifier kit (see Figure 4). This little circuit puts out up to eight watts of power into eight ohms — a good match for the speaker included with the sound module kit. It gave me the punch I needed so the train sounds could be heard throughout the restaurant.

Is There Anybody ... Out There?

The train was now able to be called into action on demand, play sounds that would relate to its actions, and run automatically on timed intervals, I thought I was finished adding features. However, one of the folks working at the restaurant pointed out that the train continued to run even if the dining area was empty of patrons. If we could cause the train to sleep when no one was in the dinning hall area, we could further extend the life of the engine and also reduce the annoyance factor for the staff (they do get tired of hearing the bells and whistles of the train after a while).

I added a motion sensor to the Prop-1 and added some code to keep track of the amount of time elapsed since the last time the motion sensor had seen movement. If that time amount reached a predetermined minute threshold, the train would be put to sleep and would cease to auto-add laps. This also made it possible for the train to sleep overnight in the event the staff forgot to turn the train off at the end of the day.

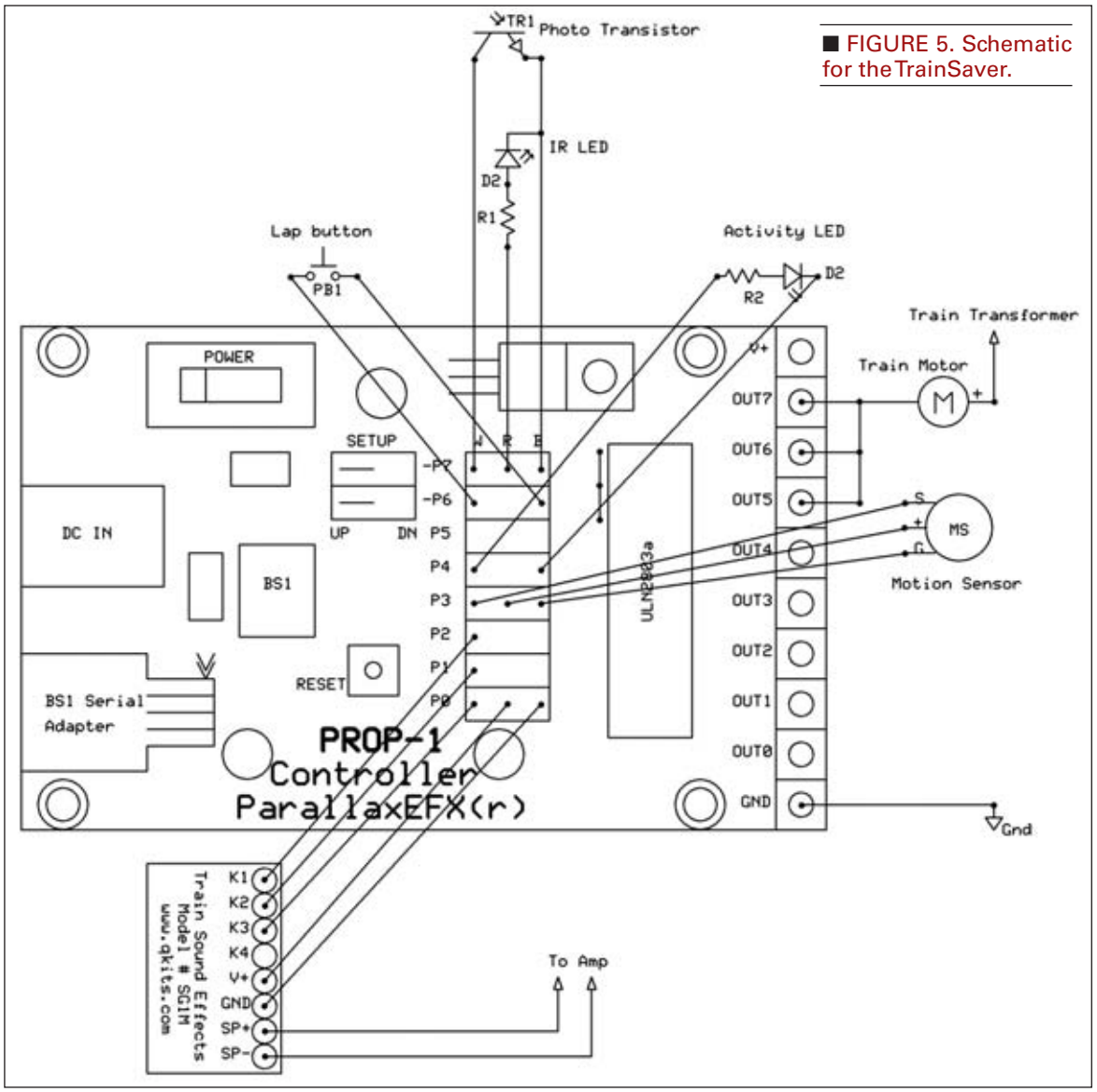
Put Your Parts Together Now!

So, now that I had all my parts and some successful testing under my belt, it was time to break out the soldering iron and create the final version that would be permanently mounted at the restaurant. The Prop-1 comes pre-assembled with the ULN2803a, the LM2940 +5V regulator, and .100 spacing headers for each of the I/O pins. It would be the heart of this project. I allocated the Prop-1 pins in this way (see Figure 5):

- Pin 0 — Sound Module (Crossing Bell sound)
- Pin 1 — Sound Module (Clickety/Clack sound)
- Pin 2 — Sound Module (Whistle sound)
- Pin 3 — Motion Detector
- Pin 4 — LED Indicator Light
- Pin 5 — Power to Train Motor
- Pin 6 — IR Phototransister
- Pin 7 — NO Pushbutton

The assembly of the components into a small finished box is fairly straightforward. I started by soldering together the COB sound module kit, then the eight watt amplifier kit. With the two kits assembled, I now needed to fabricate the IR transmitter and receiver.

The pin spacing on the Prop-1 is .100" and is a perfect match for extra



■ FIGURE 5. Schematic for the TrainSaver.

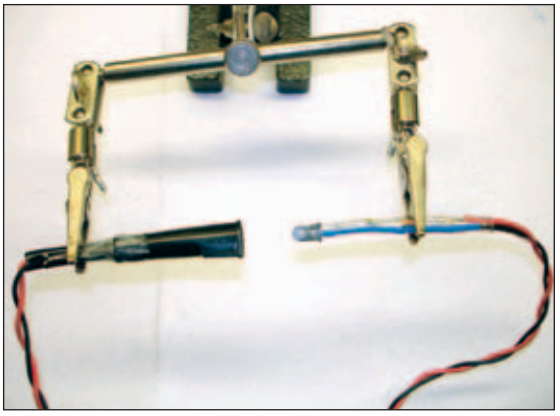
CD-AUDIO cables I happen to have laying around, so I decided to salvage them for their connectors. Since the Prop-1 has +5V (labeled "R"), Gnd (labeled "B"), and IO (labeled "W") arranged for servo connection, I would have an easy source for power and ground for the sensor and for the source IR LED.

I found some three-conductor wire from an old mic cable in my junk box and added the .100 spacing header to one end. I then created two pig-tails for the IR LED and the IR phototransistor. I used an old pen cap as the ambient light shield for the phototransistor. I placed a current limiting resistor in-line near the LED and then wrapped it all up nicely with heat shrink tubing (see Figure 6).

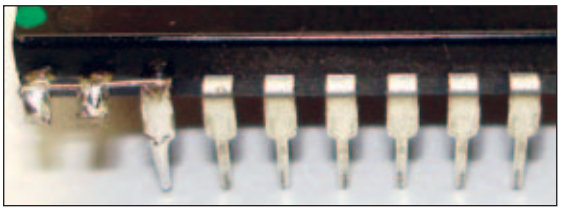
Now, with the sensor squared away, I needed to mount all the parts in the case. However, during the preliminary testing I noticed the ULN2803a was getting rather hot when switching the train. Though ULN2803a is a versatile and robust part, when I measured the current drawn by the train, it proved to be a bit in excess of the recommended max current draw for a single pin on the ULN2803a.

To make sure we had enough headroom and wouldn't burn up the chip, I ganged multiple pins of the ULN2803a to get higher current capability. The fact the part is socketed made this process easy since all I had to do was remove the ULN2803a, bend pins 1 and 2 out to 90-degree angles (see Figure 7), bridge pins 1, 2, and 3 with a bit of solder, and then replace the chip.

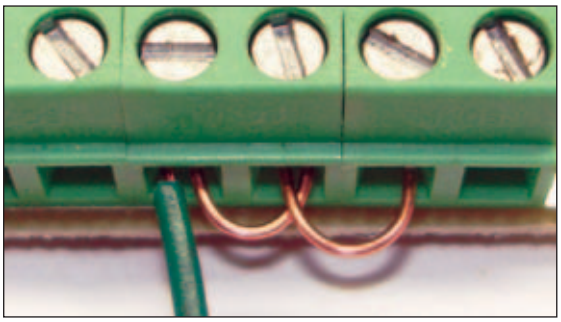
I then bridged the three corresponding ULN2803a output screw-terminals (outputs 7, 6, and 5) on the screw terminals of the Prop-1 (see Figure 8). This modification allowed the BS1 to send the PWM output to three input pins on the ULN2803a using only pin



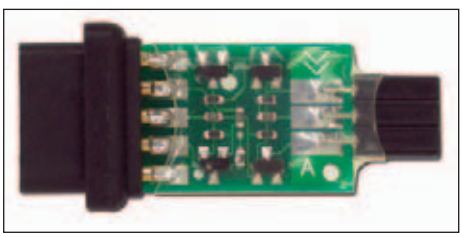
■ FIGURE 6. IR beam-break detector prototype. A pen cap is used to reduce ambient light sources.



■ FIGURE 7. The ULN2803a pins bridged to allow a Prop-1 output to control three of the ULN2803a outputs.



■ FIGURE 8. Prop-1 output terminals bridged to provide higher amperage output.



■ FIGURE 9. Parallax serial adapter. Using this, you can program the Prop-1 using a standard serial output from the PC.

5, but ganging outputs P5, P6, and P7 for a combined load capacity of approximately 1.5 amps.

NOTE: Please be aware that the ULN2803a's ability to handle current is based on total part power dissipation. If your train motor will draw more current that the chip can source, it will destroy the chip. I recommend you examine the ULN2803a data sheet to determine if your intended current draw will exceed the part specifications. If your train draws more current than the chip can handle, you might want to consider using the Prop-1 outputs to drive a relay or a high-power MOSFET instead.

■ FIGURE 10. The Prototype Prop-1 open for inspection. Note that the LED indicator is integral to the pushbutton switch. I used this combo-part since I already had it in my junk bin. You can use a discrete LED and one of the pushbuttons that comes with the Train Sound Kit.

My newly modified Prop-1 board was now ready to be mounted in the case. I used a dab of hot-melt glue to hold the Prop-1 to the bottom of the case and then cut a hole in the side of the cabinet big enough to accommodate the BS-1 serial programmer (see Figure 9). I connected the sound module's power to the Prop-1 P0 "R" and "B" power connectors. I then connected the sound module's K1, K2, and K3 pins to the Prop-1 P0, P1, and P2 "W" connectors (see Figure 10). Now that I had the connections made, I used another dab of hot-melt glue to affix the sound module to the case.

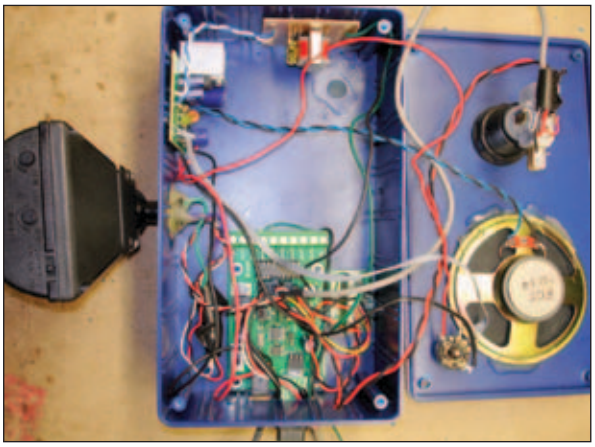
The eight watt amp kit (see Figure 11) was easily mounted in the same manner as the sound module (again, a dab of hot-melt glue) and the output from the eight watt amp kit soldered to the speaker on the inside of the box. I mounted a NO pushbutton switch with an integral LED indicator light (I had this in my junk box, but you could use one of the NO pushbuttons included with the COB sound module kit) to the inside cover of the box, and then soldered another salvaged CD-AUDIO cable to it as a pigtail and connected that to pin 7 of the Prop-1.

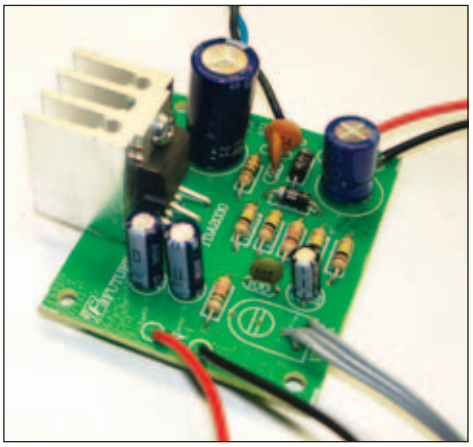
I drilled holes in the box cover to allow the sound to escape from the 3" speaker and then used hot-melt glue to mount the speaker to the inside cover of the box. Lastly, I threaded the power and IR beam break sensor cables through the hole in the side of the box. Now that I had the hardware all assembled, all I needed to do was write some code!

Go With the Flow

During the prototyping, I had written small routines to test each function of the train controller but I hadn't put all the pieces together. Now I needed a final, master program that would encompass all the functions. The software would need to control the train, the sound, read the button, sense the train position, and monitor the dining room for motion.

As the function list got longer, the coding concepts were getting quite complex. If you are ever faced with this situation, I highly recommend that you spend some time building a flow chart for your program as it will really help you to clarify your vision and help to write code to





■ FIGURE 11. Fully assembled audio amplifier.

handle every function.

Figure 12 shows a basic concept flowchart that I built before attempting to actually write code for this project. The program breaks down into these functions:

• Check if the button has been pressed. If so, add laps.

• Check value of the laps variable and stop/start the train.

• Check if the idle time has expired. If so, add a lap.

• Check if the IR beam is broken. If so, decrement a lap.

• Check if the motion is sensed, if so, reset sleep time.

• Increment all time counters.

The program takes quite a bit of space in the Prop-1's memory, but I managed to get all the functions in that I was seeking and still had enough room to add both a diagnostic mode to help align the IR beam sensor and a motion sensor walk test. At the time of this writing, the program provides the following operations:

1) Provide a test/calibrate mode for the IR LED beam.

2) Provide a walk test mode for the motion sensor.

3) Read the button and add a number of laps when pressed.

4) Decrement laps whenever the train passes through the IR beam.

5) If the train is idle for a preset time, then the train runs a single lap.

6) If room is empty for preset time, put the train to sleep.

7) Play a sound when the train starts up (Train Whistle).

8) Play a sound when the train stops (Crossing Bell).

9) Play a sound when the train is passing the IR sensor (Click/Clack).

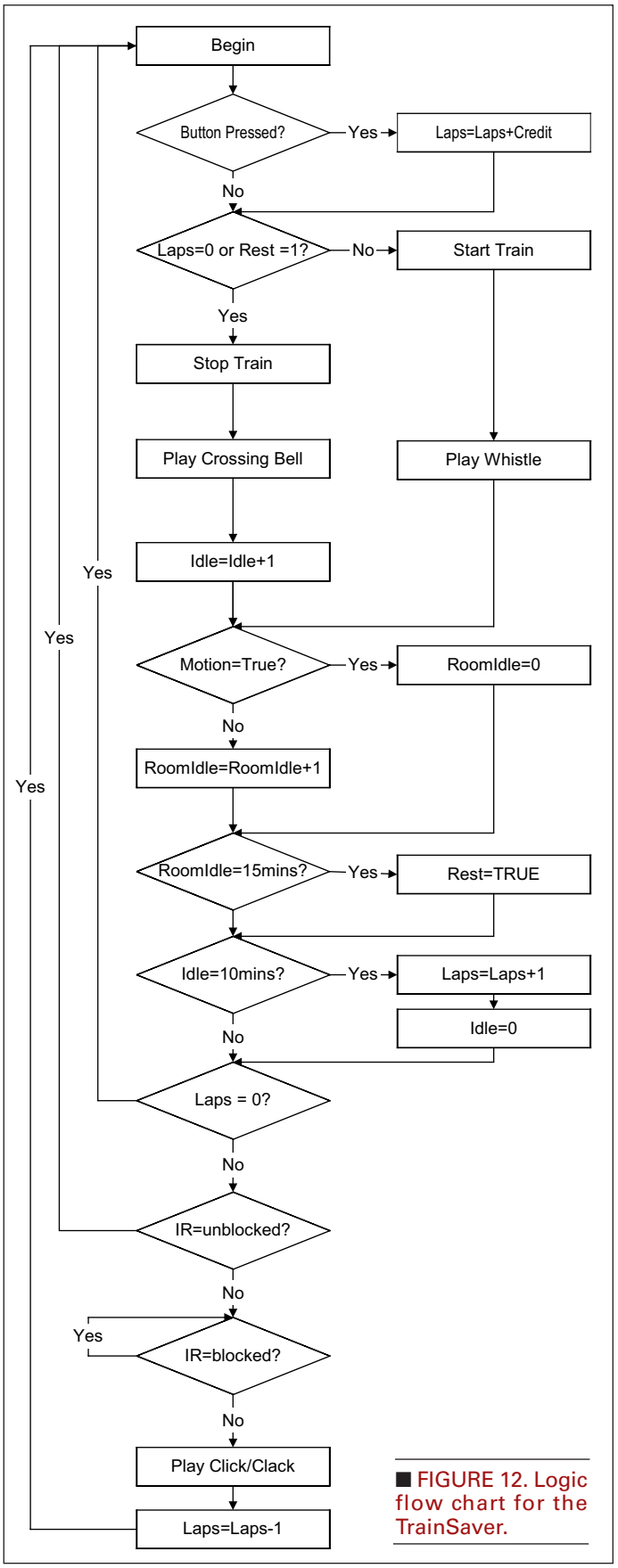
10) Blink the LED to indicate the number of laps remaining.

Testing ... Testing ... is This Thing On?

Now that we had implemented all the functions in a complete program, it was time to set up the system and test it out on my workbench. The first thing needed for testing is power. I used a nine-volt 500 mA filtered power supply to run the microcontroller to insure it had clean power. Make sure the switch on the Prop-1 is set to the 0 position, then connect the transformer to the Prop-1 power connector. Now we need to connect the unit to the train like this:

• Connect the GND wire from the train transformer to the GND connector of the Prop-1.

• Connect the positive wire from



■ FIGURE 12. Logic flow chart for the TrainSaver.

the train transformer to the positive connector for the train track.

• Connect the negative connection on the train track to "output 5" on the Prop-1. (Be careful not to dislodge the jumpers between outputs 5, 6, and 7!)

WARNING: Check the polarity of the train transformer output and make SURE you do not reverse the voltage provided to the Prop-1 screw terminals! Reversing the polarity (by placing the train transformer into reverse) can destroy the ULN-2803 or other components! If you believe there is a danger of this occurring, you might want to place a 1N4001 diode in series with the train power source to block reverse voltage from the circuit.

Turn on the train transformer and set the speed to approximately 50%. Now, turn the switch on the Prop-1 to the 1 position.

WARNING: If you use the 2 position it will attempt to join your wall-wart supply to that of the train power supply! This could destroy the Prop-1 controller!

Once you have the Prop-1 showing power, it's time to download the program. Open the Parallax BASIC Stamp Editor and load the source code (available for download from the website shown at the end of this article). Once the source code is loaded, locate this section near the top of the program shown in Listing 1.

These settings should be examined and understood before changes are made. To better understand these settings, here are some short summaries of the settings and what they do:

TrainIdleTarget: This value is used to determine how long you want the train to wait between automatic laps. The default value is 10 minutes. The idea is to reduce the total amount of runtime on the train engine while still having the train perform often enough to be interesting to observers. If the train were to run continuously, it would not only wear the train out sooner, but people would rapidly lose interest. In a restaurant situation, having the train run on 10 minute intervals means an average patron will see three to six laps during an average meal.

RoomIdleTarget: This value is used to determine how long the performance area of the train remains empty before the train is put to sleep. This further reduces the total runtime accumulated by the engine and also gives the staff a break from the sounds the train makes.

MaskTime: This value is set in milli-seconds and reflects how long you want to ignore the IR beam-break sensor after it is tripped. This value setting is critical if you are unable to set the IR beam sensor so it stays interrupted the entire time the train and cars are present. You will need to set this value to cause the sensor to wait until the entire train has passed the sensor before decrementing a lap.

Credit: This value determines how many laps are added to the train for each press of the button. If the button is replaced with a coin mechanism, this can be used to determine how many laps are given in return for a coin. Most coin mechanisms have a SPDT switch that is used to detect the coin. Simply replace (or wire in parallel) the coin switch with the existing NO pushbutton.

LapLimit: This allows you to limit how many total laps may be added to the train. This value was added to limit how many laps could be added if someone pressed the lap-button repeatedly. In our testing, we discovered that sometimes the staff would rapid-press the button multiple times adding *lots* of laps (i.e., 10 or more rapid presses at five laps each!). This insures that we don't over run the train.

Once you've adjusted these settings, download the code to the Prop-1. If the download is successful, hold down the lap button and press the reset button on the Prop-1. The program checks to see if the lap button is in a down position on startup. If so, it will enter a calibrate mode where it simply illuminates the indicator LED when the IR beam is intact, and then extinguishes the LED when the beam is broken. This allows those of us who cannot see into the IR spectrum to align the LED IR source with the phototransistor sensor across the track.

Now that you can see the

LISTING 1

```
'-----------------------------------------------------
' Initialize Train System Variables
'-----------------------------------------------------
   HIGH LED                        ' Turn off the LED in the button
   SYMBOL TrainIdleTarget = 10     ' Minutes of idle before a lap is added
                                   '  for the train to run (values 0-254)
   SYMBOL RoomIdleTarget  = 15     ' Minutes without motion before the train
                                   '  is put to sleep (values 0-254)
   SYMBOL MaskTime        = 1000   ' How many MS to wait b4 we check for the
                                   '  end of the train after beam-break.
   SYMBOL Credit          = 5      ' Number of laps added by a button press
                                   '  (or coin drop)
   SYMBOL LapLimit        = 9      ' Set the maximum number of laps that may
                                   '   be added
   SYMBOL TicksPerMinute  = 4000   ' 4000 ~number of ticks that pass in a minute
                                   '  Note that if you alter the loop length you
                                   '  will have to recalibrate.
   SYMBOL TunnelDelay     = 6000   ' Delay from end of train till stop execution
                                   ' (allow train to traverse tunnel)
```

alignment of the IR sensor, pick an appropriate position on the track where the train will reliably interrupt the beam when it passes. The mouth of a tunnel or the start of a bridge span are good locations. If possible, I recommend placing the sensor at a height that will keep the beam continuously interrupted between the train cars. You can accomplish this by placing the sensor at the level of the coupler between cars. If this is not possible, you may need to adjust the mask value in the program to allow for all the train cars to pass the sensor before you decrement a lap, otherwise each train car that passes the sensor would decrement a lap!

Once you have the beam aligned, it's time to test out the motion sensor. Press the lap button one time to drop into the walk-test mode. The LED will illuminate each time that motion is detected. Try holding very still and see if the LED goes out. If it does, you know that the motion sensor is working. Now press the LAP button one more time to exit the calibrate mode. Once out of calibrate mode, the system is waiting for either the lap button to be pressed or for enough idle time to pass to cause a lap to be added to the lap counter.

To have the train start, simply press the lap button one time. This will add five laps to the train (the number of laps added by a single button press is adjustable in the software). A single blink of the indicator LED will acknowledge the five-lap credit has been added. The train whistle sound should play and the train should slowly start up and begin to move around the track.

When the train gets to the point where it interrupts the IR beam, the indicator LED on the TrainSaver box should blink the number of laps remaining before the train will stop and the click/clack sound should play. When the laps value has been reduced to 1, and the train breaks the IR beam, the train will slow to a stop and the crossing bell sound should play.

If no one presses the laps button for 10 minutes (or whatever number you set before you downloaded the code), the TrainSaver will add one lap to the lap counter, the train will play the whistle, run one lap, and then halt to the accompaniment of the crossing bell sound. If everything operates as described, then you have a working TrainSaver! Congratulations!

Plug it In, Plug it In ...

Once we completed the bench testing described above, it was time to head out to our BBQ restaurant early on a Saturday morning armed with ladders, tool boxes, drills and all the other bits and pieces we thought we would need. We mounted the TrainSaver box on a wall adjacent to the cash register so the cashier could easily add laps to the box, but placed it high enough on the wall to make it difficult for children to add laps themselves.

We removed the ground lead from the track and ran it into the TrainSaver box and attached it to the Prop-1 screw terminal 5 (being careful not to alter the jumpers between terminals 5, 6, and 7). We then ran a line from the Prop-1 GND screw terminal to the GND connector on the train transformer. I plugged in the wall-wart power supply and turned the power on while holding down the lap button on the unit, thereby placing it in diagnostic mode.

Then, while watching the LED to make sure we had the sensor lined up with the IR LED, we installed the sensor across the tunnel (see Figure 13) making sure the sensor height was at the same level as the engine-to-car coupler. (*Note: This is important to insure the short gap between the engine and the cars doesn't cause extra decrements of laps as each car passes.*) I pressed the button to drop the unit out of diag/calibrate mode and we were ready for our first real test.

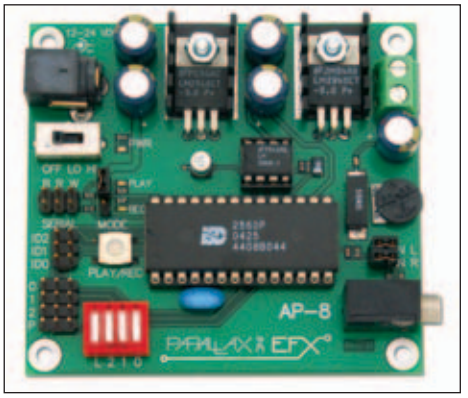
Crock Full O' Trouble!

We pressed the lap button, the whistle sounded, the train engine started up, and the train headed around the track! Success! We then noticed that about halfway around the track, the TrainSaver unit sounded the click/clack sound and the LED blinked to indicate that the unit had decremented a lap. We were surprised since the train was no where near the sensor when this occurred.

When the train did arrive at the sensor, the click/clack played and a lap was decremented as expected. Though puzzled, we chalked it up to an anomalous IR reflection or some other random event that could be ignored. However, as we were packing up our tools, we noticed that the train began to decrement laps every so often when the train was in the middle of the track, sometimes

■ FIGURE 13. The IR beam-break sensors mounted on the train tunnel entrance.

■ FIGURE 14. The ParallaxEFX AP-8 serially controlled digital sound playback unit. If this were used to substitute for the COB sound effects module, it would free up three IO pins on the Prop-1, allowing for expanded functions and more sound effect events.



Author Bio

■ *Vern Graner is a Senior Systems Engineer with a Software Company in Austin, TX. Though married with two kids, he still finds time to create electronic projects in his so-called "spare time." You can contact him via email at vern@graner.com*

causing the train to halt without parking in its assigned location (the tunnel). Something was obviously wrong ... but what?

We double-checked the connections and checked the software but everything seemed to be set up correctly. While I was going over the source code, my son mentioned that a crock pot on a shelf below the train transformer would make a buzzing sound each time that a false lap was detected. With more investigation, we discovered that this crock pot had an old thermostat that was arcing and generating *lots* of noise! It appeared that the interference was being picked up by the IR sensor wire and being interpreted by the software as the train breaking the beam!

Based on this theory, I added a few lines of code that would check the state of the IR sensor and make sure it stayed in a "beam is broken" state for at least 100 samples before it would acknowledge the reading as valid. Once the False Detection code loop was added, the false laps disappeared! Problem solved and the TrainSaver was done!

Future Expansion

Though I'm happy with the current incarnation of the TrainSaver, I've already been brainstorming about future improvements to this device. For example, the pushbutton switch could be replaced with a coin box that would allow patrons to drop a coin to receive a preset number of laps from the train. This would allow the owner of the train system to recoup some of the inevitable cost of repairing or replacing a train engine when it wears out. An external speaker could be placed inside a tunnel or in a fake building near the station where the train stops so the sounds would appear to come from the vicinity of the train.

You could opt to reduce the number of sounds (i.e., remove the click/clack) and dedicate that pin to controlling a relay that would switch the

Resources

■ Vern Graner's "TrainSaver" website
www.trainsaver.com

■ Parallax, Inc.
www.Parallax.com

■ The Robot Group of Austin
www.robotgroup.net

sound between speakers on different parts of the track. You could opt to free up three pins by replacing the COB sound module with the ParallaxEFX AP-8 (see Figure 14) serially controlled audio board. This would let you trigger up to eight sound effects while using only ONE pin on the Prop-1.

Since the configuration of the Prop-1 is already set up for a servo to be directly connected, one could be attached to a pin and code added to control an automatic crossing gate (lift and lower the barrier as the train passes).

It's amazing to me that with such a small and inexpensive controller, there's still so much room for exploration! If you decide to build a TrainSaver, I invite you to visit **www.TrainSaver.com** and exchange ideas, messages, and code improvements with others working on this neat little project. **NV**

PARTS LIST

ITEM	DESCRIPTION	SUPPLIER	PART NO.	PRICE
❑ Microcontroller	Prop-1	Parallax	31101	$35
❑ Serial Programmer	BASIC Stamp 1 Serial Adapter	Parallax	27111	$4.95
❑ Motion Sensor	PIR Sensor	Parallax	555-28027	$7.95
❑ Sound Module	Train Sound Generator Kit	Quality Kits	SG1M	$7.95
❑ Amp	Eight Watt Audio Amp Kit	Quality Kits	FK604	$6.49
❑ IR LED and Sensor	Matched Infrared Emitter and Phototransistor Detector	RadioShack	276-142	$3.29
❑ Project Case	8" x 6" x 3" Project Enclosure	RadioShack	270-1809	$6.99
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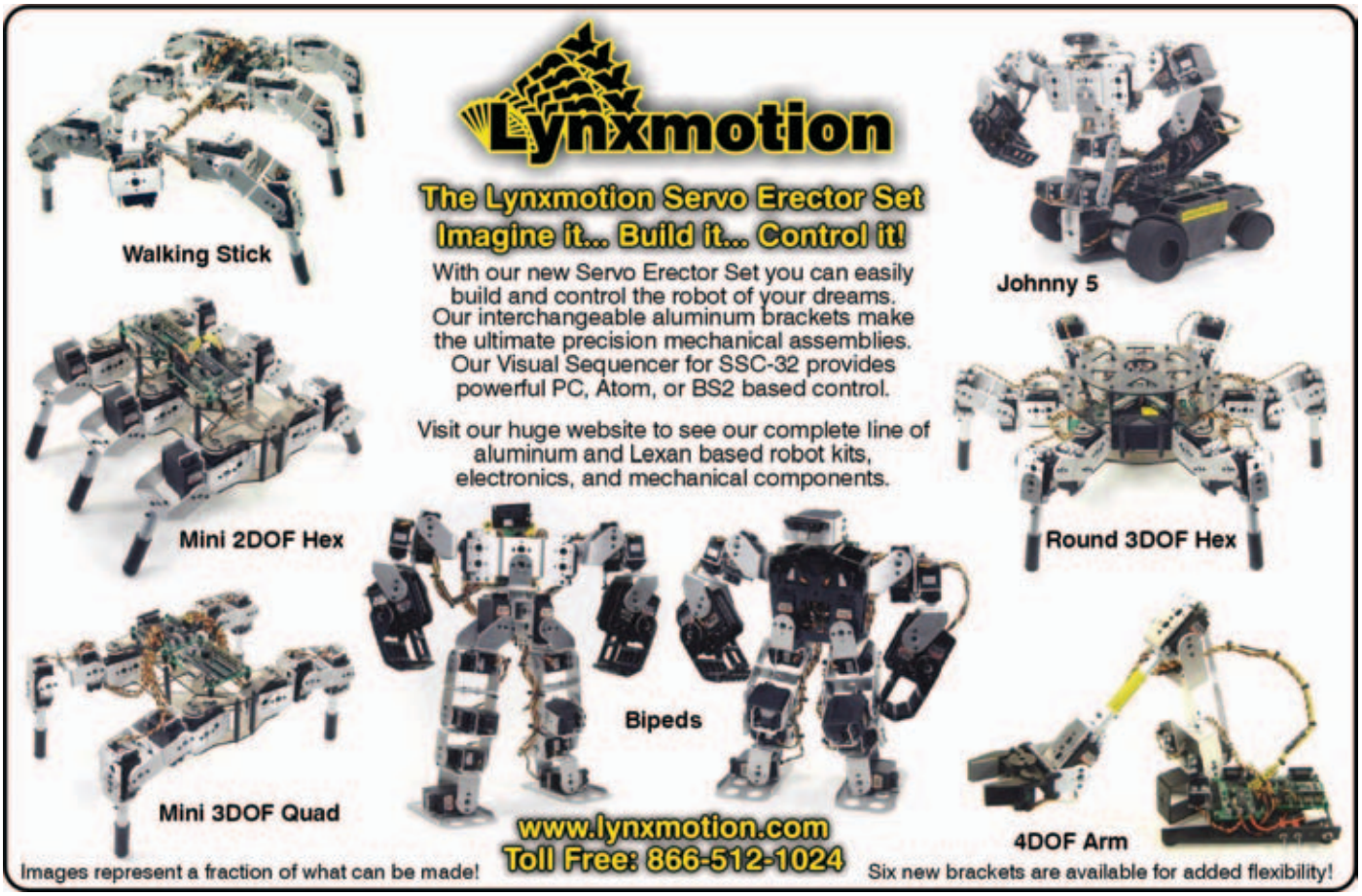

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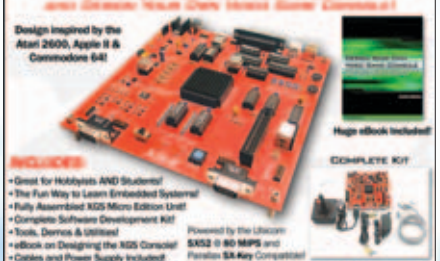

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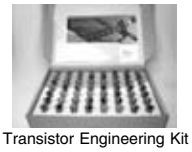

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RADAR and ELECTRONIC WARFARE Fundamentals

BY GERARD FONTE

RADAR AND ELECTRONIC WARFARE (EW) *are usually thought of as being very complicated and very secret. And while this is true for specific designs and detailed theory, many of the basic principles are straightforward and easy to understand. This article will present some of the fundamental concepts of radar and show how EW develops from that.*

RADAR BASICS

As most folks know, radar (RAdio Detection And Ranging) came of age in World War II. And everybody knows that radar sends out a radio signal that bounces back from an object. The range (distance away) of that object is determined by timing how long it takes for the echo (return signal) to come back. Most everyone has seen huge parabolic antennas rotating in circles, scanning the sky for incoming airplanes or missiles. At the least on TV and the old sci-fi movies. Many radar systems use such antennas. But some don't.

It's also important to remember that the antenna performs two functions. It acts as a transmitting antenna for the out-going pulse and as a receiving antenna for the return signal. This means that the transmitter must be disconnected (or turned off) during the time you want to listen for a return signal. Otherwise, any return signal will be overwhelmed by the transmitting pulse. Additionally, precautions must be made so that the receiver front end isn't damaged or destroyed by the powerful transmitting pulse.

Let's examine the basic radar geometry and design factors. Signal strength is a critical factor in the performance of any radar system. Obviously, if you can't detect the return signal, you can't detect the object. The more powerful your transmitter is, the greater the potential range of the radar. The larger the transmit/receive antenna, the greater the range. The larger the target (called Radar Cross Section or RCS) the stronger the return signal and the greater the range. While not obvious, the longer the wavelength, the less signal loss there is. So lower frequencies are better. (However, lower frequencies mean larger and heavier antennas.)

Of all these factors, the range (distance to target) is the most critical factor. This is pretty obvious when you think about it. A transmitter's signal decreases by the square of the distance. Twice the distance means one-quarter signal strength. But the return signal decreases by the square of the return distance, as well. So, the return signal decreases in strength to the fourth power of the distance. So, doubling the distance to the target results in 1/16 of the signal being returned (all else being equal).

It's for this reason that radar transmitters are immensely powerful. They can transmit very short pulses (about 50 µS) that are tens of megawatts and more. For example, the AWACS (Airborne Warning And Control System) klystron-type transmitting tubes are rated at 50 megawatts peak pulse power. Since the pulses are short and the repetition rate (or pulse rate) is about 1,000 pulses per second, the average power is much less — about 250 to 500 kilowatts. But that's still plenty powerful. Of course, not all radars are this powerful. Some portable or weapons radars are only a few watts.

In order to locate an object, both its range and direction need to be determined. The range is obviously determined by the delay of the return signal. The direction is determined by where the antenna is pointing. If this seems rather crude, you're right. Directional sensors measure the elevation angle and the azimuth angle (compass heading).

Naturally, the radar antenna must be properly aligned and calibrated so that its elevation and azimuth angles agree with the real world (or with the ship's bow or missile's flight direction). The angle sensors are often "synchros" or "resolvers" which are a special type of transformer and will not be discussed further.

Acquisition and Targeting Radar

There are two general classes of radars: acquisition and targeting. The acquisition radars are the big, stationary, long-range kind while the targeting radars are usually smaller, portable, and shorter range (sometimes being the guidance system of a weapon). They have two different functions.

Acquisition radar is used to detect objects from a long distance away. Since the object is a long way off (sometimes thousands of miles), its position, relative to the radar, can't change all that much in a few seconds. For that reason, acquisition radar only illuminates (or "paints" or "lights up") an object once every revolution of the antenna (which is typically every few seconds or so).

For reference, a airplane moving at 700 mph, or the speed of sound at sea level, only travels about 1,000 feet per second. A 2,000 or 4,000 foot difference at 100 miles is not too significant. Acquisition radars are the typical types shown in the movies and were the types used in WWII.

Targeting radars are used to guide weapons to a target. Sometimes these are ground-based radars and sometimes these are incorporated into the weapon itself. A "guided" missile is one that is directed by ground-based radar to a target. A "homing" missile directs itself from the radar reflection.

Note that a homing missile can use a ground-based radar to illuminate the target. And in the early days of radar this was very useful because it meant the missile didn't need a radar transmitter. However, if the illumination signal was lost for whatever reason, the missile would "lose track" (or "lose lock") and fail to hit the target.

Additionally, it meant that a ground radar was dedicated to that target for the duration of the missile's flight. That's not a problem if there are only a few slow airplanes coming at you. But with today's vast numbers

of fast fighters/bombers, this approach is not used too much.

The fundamental difference between acquisition radar and targeting radar is the idea of "radar lock." Acquisition radar loses lock and re-acquires (re-detects) the object during every revolution of the antenna. Targeting radar must never lose radar lock because it has no real means of finding the target to begin with.

A targeting radar is always initially directed to a target by some outside means. This could be by linking it with an acquisition radar system, which is typical for ground-based missiles. Or, it could be by actually pointing the missile at the target and allowing the missile-radar to lock on, which is typical for air-launched missiles. Since it is imperative for a targeting radar to maintain lock, it must send out radar pulses at a much higher repetition rate, often at 100's or 1,000's of pulses per second. It can't allow the target to move too far between pulses or radar lock could be lost. And at close range, there can be considerable relative-position changes at high-speeds. Therefore, high pulse rates are the key indication that a targeting radar is in use.

Radar System Signatures

Since radar systems are expensive to design and develop, there are a limited number of systems in use around the world today (perhaps a few hundred). Clearly, it is important to know what particular radar system you want to defeat before you can design a particular defense or countermeasure.

There are a handful of characteristics that identify a given radar system. The first is the frequency of operation. The second is the pulse length. The third is the pulse repetition rate. The fourth is the scanning rate or the time it takes for the antenna to rotate 360 degrees. The fifth is the antenna radiation pattern which is broken down into the "main lobe" and "side lobes." These side lobes turn out to be a very significant weak point in any radar system and can be used to create confusion and misrepresent the target.

A radar "beam" is not just one beam. It's really a number of beams. Figure 1 shows a typical radar antenna pattern. There is one main beam (or main lobe or focal point). This is where the antenna is actually pointing and has the most power during transmitting and the most sensitivity while receiving. But no antenna is perfect. There are actually a number of secondary beams called side lobes. These are identified in Figure 1. Typically, the two major side lobes have a reduced sensitivity of only 10 dB to 15 dB relative to the main lobe. We'll see how this can be employed for EW in more detail, later.

Basic Radar Countermeasures

There are two radar countermeasures than have been used for some time: chaff and jamming. Chaff started in WWII and consisted of airplanes dropping aluminum-foil strips — called chaff — to create multiple reflective targets and to block radar beams from penetrating (like a smoke screen). Chaff is effective for both of these functions if the length of the aluminum-foil strips is appropriate for the radar frequency that is being used. If the length of the foil is too different from the radar wavelength, it loses its effectiveness. (This is why it is important to know the radar signature before attempting countermeasures.)

Jamming is another method of defeating radar. It consists of transmitting continuous signals directly at the radar antenna that are the same frequency of the radar. Since a transmitter can be much more powerful than a radar reflection, it will present the receiver with a large signal and the weaker return signal will be masked. This significantly reduces the effective range of the radar. Eventually, the target will get close enough to the radar system so that the radar return signal will be larger than the jamming signal. When this occurs (called burn through),

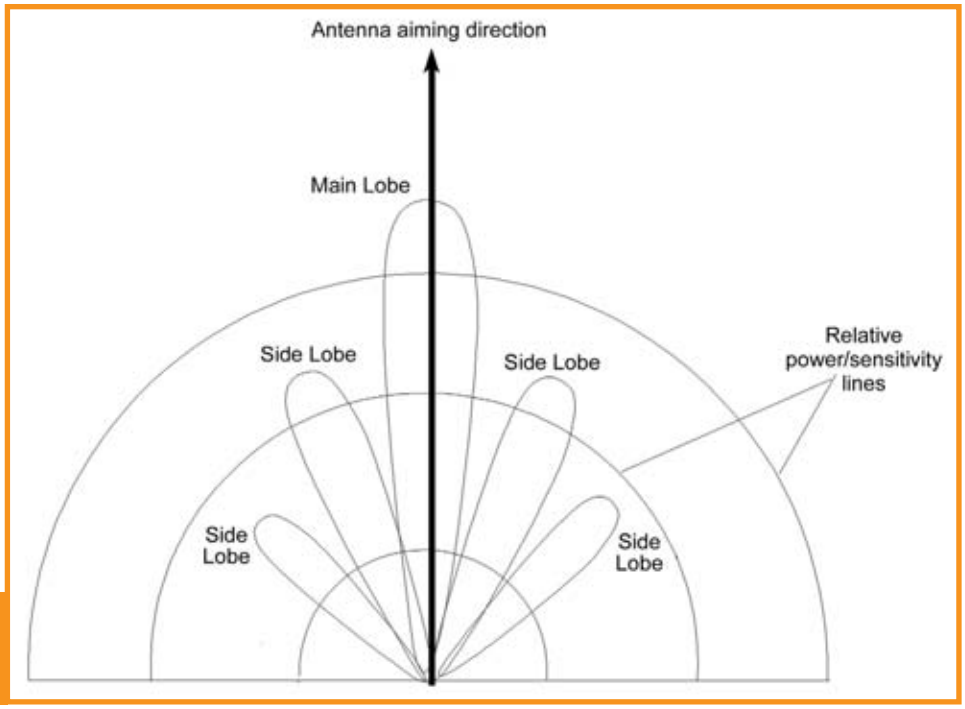


FIGURE 1. A typical polar plot of a radar antenna sensitivity pattern. Note that the side lobes are only 10 dB to 15 dB below the main lobe.

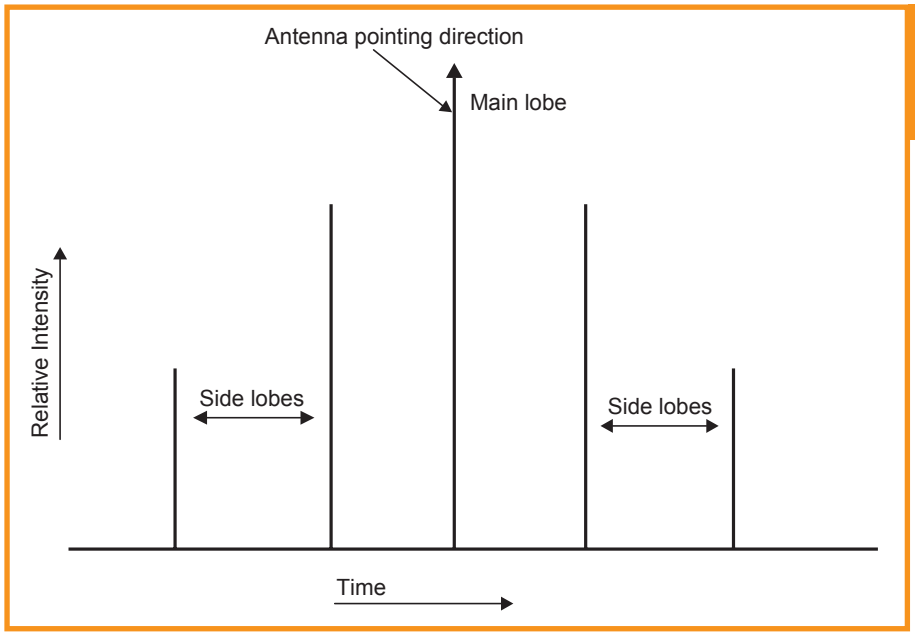


FIGURE 2. A stationary receiver detects a series of signals as the radar antenna rotates. The amplitude of the signals is related to the main lobe and side-lobe pattern, as shown in Figure 1.

normal radar operation can be resumed.

Note that powerful jamming transmitters can be located so far away to be virtually untouchable. Also, due to the side lobes of the antenna, the jammer can affect multiple sectors (angles) of the radar. The radar display shows "spokes" of interference that are related to the side lobe pattern. Therefore, there are several directions that can hide incoming targets. Multiple jamming transmitters, it different locations, can create additional interference/spokes and reduce the effectiveness of radar to a significant degree.

ARMs and False Targets

An Anti-Radiation Missile (ARM) is arguably an EW component. It's actually a missile that is designed to lock on to a radar signal (or "radiation"), home on it, and destroy the antenna and anything close by. It's a fairly simple idea that is somewhat harder to put into practice. This is because there are many different radar signatures that the missile must be programmed for. You obviously wouldn't want one to target your own radar signal.

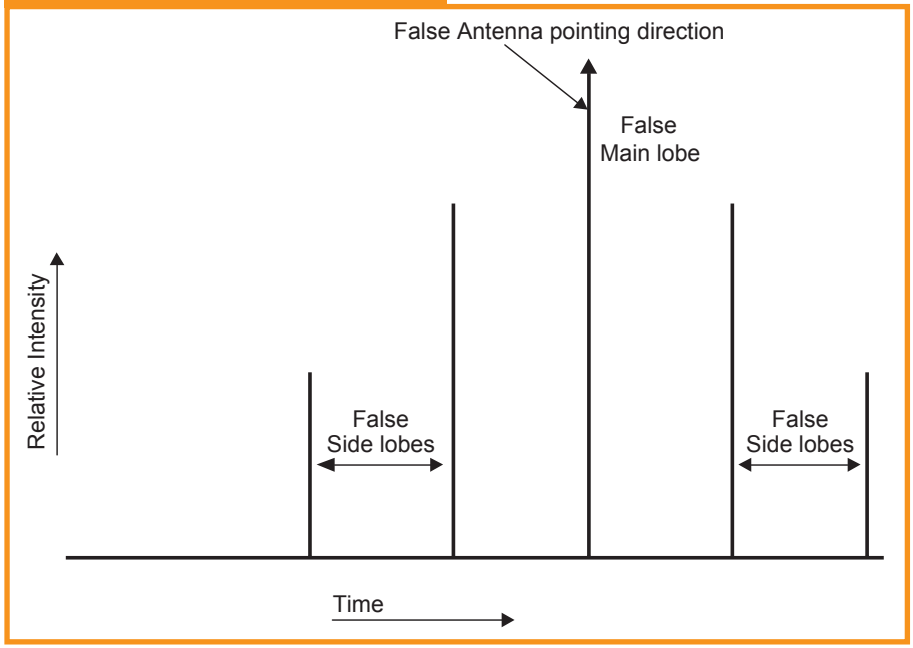
ARM missiles put the radar operator in a dilemma. If they use the radar to search for targets, they expose themselves. (Literally, it's like a search-light at night.) If they turn off the radar, they are no longer exposed but they are also ineffective. Neither choice is appealing.

False targets can be created several ways. The simplest is a form of jamming. Instead of transmitting a continuous signal, pulses that match the radar signature are transmitted. So instead of spokes on the display, there are many dots that look like targets. Trying to find a real target among hundreds of false ones is not a trivial matter.

A more sophisticated method of false target generation uses the Achilles heel of radar or the side lobes. As noted before, the side lobes are often only 10 dB to 15 dB below the main lobe in sensitivity. So, if you transmit a "return pulse" that matches the radar's signature while the side lobe is pointing at you, the radar will think it is a main-lobe reflection. The result is that the antenna is pointing in the wrong direction and any weapon than is controlled by that radar will be aiming at a false target.

Let's examine this in more detail. As you approach a radar, you will be able to obtain its signature before it detects you. (This is because the return signal must travel all the way back to the radar.) Your radar receiver will detect pulses of different strength as the acquisition radar antenna rotates. Figure 2 shows a typical pattern with typical side lobes. Since you

FIGURE 3. Knowing what the radar signature is from Figure 2, a false return signal can be created.



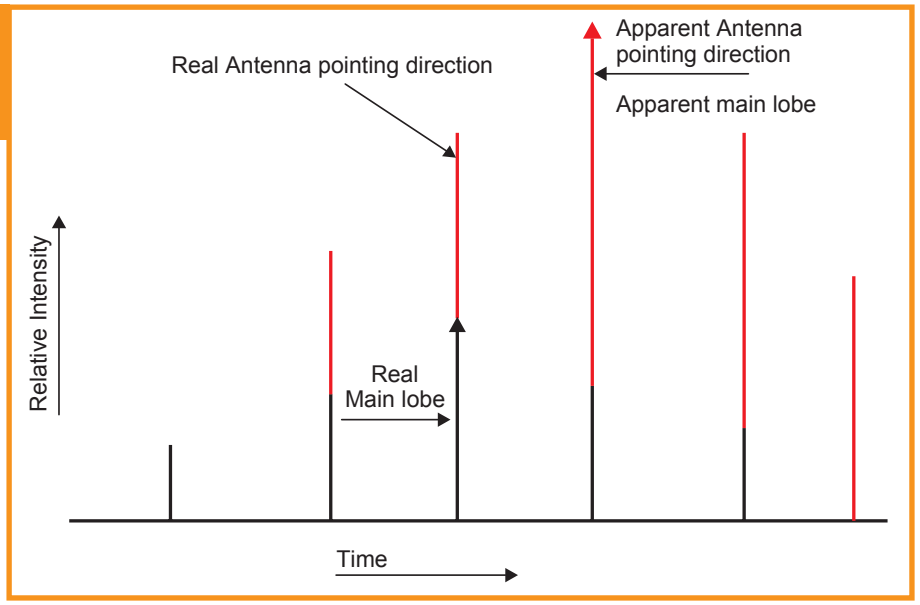


FIGURE 4. Combining the false signal with the real signal creates a false signal that appears real to the radar. The radar antenna is pointing in the wrong direction when the largest return signal is received.

know the RCS of your craft, you can estimate when the radar will detect your return signal. Before that time, you (your computer actually) create a return signal of your own. Figure 3 shows such a constructed return signal.

Then you transmit this false return signal at just the proper time in the radar signature so that the largest return signal appears on a radar side lobe. The radar system assumes that the largest return signal occurs in the main lobe. But in this case, it isn't. The radar antenna is actually pointing in a significantly different direction from you. The error can be as much as 30 degrees. So, if this acquisition radar directs a weapon at you, it's really pointing in the wrong direction. (Figure 4 shows how this happens.)

If that weapon has a targeting radar, it is very likely that it will never achieve lock-on because you will be out of its field-of-view. With proper timing, these false return signals can be made to "move" at any speed or direction (within limits). Multiple false targets with multiple headings can be generated with a single side lobe transmitter. Such an approach can be used, to a degree, with targeting radars, as well. But it is harder because of the higher pulse rates and because targeting radars don't re-acquire the target and expose their side lobes as much.

Other Topics

This article barely scratches the surface of this topic. There is much, much more. Phased-array and doppler radars have their own strengths and weaknesses. Stealth design and some tactical maneuvers can cause problems for radars.

> "EW is like a chess game. Every move by one side is answered by the other side."

The field of EW is usually broken down into ECM (Electronic Counter Measures) and ECCM (Electronic Counter-Counter Measures). The basic approaches described here fall into the ECM category. There are methods for reducing the effectiveness of jamming, chaff, and false targets. These methods are ECCM.

EW is like a chess game. Every move by one side is answered by the other side. The competition will continue until the day that humans have thought up every possible method of ECM and ECCM. That day appears to be in the far future. **NV**

A SNIP HERE, A CIRCUIT THERE

We've all done it — ganged multiple printed circuit board (PCB) templates onto a single piece of single- or double-sided copper clad board. Although this form of PCB fabrication frugality can save you time and money, it becomes a real labor of love as you cut each template apart. However, now you can put your band saw in the corner and use a pair of snips or scissors to separate your next big batch of PCBs.

The Electronic Goldmine (**www.goldmine-elec.com**) has a new PCB fabrication product that can be cut with scissors. Sold as either 5-1/2″ x 6″ (G15697) or 5-1/2″ x 12″ (G15698) single-sided copper clad boards, these products are exposed and etched just like their stiffer competition.

Measuring only .016″ thick, these boards are flexible and easily cut with a pair of aviation snips. Best of all is the price. Recently, the 6″ version was being sold for 99¢ each, while the 12″ bigger brother was commanding a reasonable $1.75.

This flexibility in these board's composition might enable the creative circuit experimenter to build some unconventional PCB designs. Just make sure that you don't accidentally pop a solder joint off of your curved PCB as you "roll your own."

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If you've been looking for that perfect electronic design system (EDS) software package, then look no further than McCAD. Published by VAMP, Inc. (**www.mccad.com**) — a company whose name sounds like a bad (or, good) vampire website URL — McCAD has been around for over 29 years, making McCAD one of the original PCB CAD programs.

Originally, McCAD was only available for the Mac OS. Today, there is both a Mac OS X version and a PC Microsoft Windows (98/ME/NT/2000/XP) version.

Whichever version you opt to use, the McCAD EDS enables the circuit designer to create schematic diagrams, capture these designs into PCB layouts, and generate Gerber-format files. Additionally, there is an auto-routing feature that will help you quickly add traces to your layout.

And McCAD EDS is a snap to learn and use. Just click, drag, and drop from a large library of readymade analog and digital outlines. Or, if you have an unusual IC pinout, you can edit and create your own McCAD-compatible outline.

You won't get stumped using McCAD EDS, either. There is ample online documentation for supporting the McCAD EDS. Both web-based files and a couple of hefty PDF files will help to answer any software usage question. In fact, within a couple of hours of installing the McCAD EDS you can have your first PCB template reading for etching.

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and board dimensions (6" x 6"), then you can use the McCAD EDS for FREE – either the Mac OS or Windows version. There is also a FREE Gerber File Viewer for 274-x format plotting documents. None of these FREE packages employs any other form of file crippling or expiration date system. Just stay within the restrictions and you can design schematics and PCBs for FREE.

Otherwise, professional designers can elect – at anytime – to upgrade the FREE versions of either McCAD EDS format for under $1,100.

BRIEFLY NOTED

The OpticSlim M12 Plus draws power from your PC USB port. Photo courtesy of Plustek, Inc.

Plustek (**www.plustek.com**) now offers a portable sheet fed scanner that is ideal for notebook PC road warriors. The OpticSlim M12 Plus can rip a PDF file with the push of a button. Capable of scanning letter, legal, and A4 sized documents, photos, as well as providing OCR support, the OpticSlim M12 Plus produces a resolution of 600 dpi. In keeping with its portable stature, the power for this scanner is drawn from the USB port of the host PC. There's no extra power cord or bulky power brick.

Tired of those pesky USB flash "thumb" drives? Here are a couple of more capable and sizeable options:

• EDGE Tech Corp. (**www.edgetechcorp.com**) announced their newest pocket-sized storage tool – the DiskGO one-inch Mini Portable Hard Drive. Small enough to fit into a pocket, the unit is powerful enough to hold large amounts of data. The DiskGO Mini Hard Drive requires no driver or software installation, except for Windows 98 systems. This sleek, aluminum-encased portable hard drive with anti-shock technology is offered in capacities ranging from 4GB to 8GB, at prices from $109 to $149.

• US Modular (**www.usmodular.com**) is also entering the USB drive market with the Stainless Steel Monstor Drives. Priced from $99 for the 2GB flavor, the Monstor Drive fits in the palm of your hand, requires no extra software drivers, and runs on both Mac and PC computers. There are 2GB, 4GB, and 8GB Monstor Drive options currently available.

• Now, if you'd rather "roll your own" portable hard drive, US Modular offers the Dragon Drive. This is a 2.5" external hard drive enclosure which enables anyone to "build it yourself" – a high capacity portable storage device. The Dragon Drive turns any 2.5" hard drive into a convenient portable storage drive that can be used on any system with a USB or Firewire port. The aluminum casing protects the drive from overheating and vibration. **NV**

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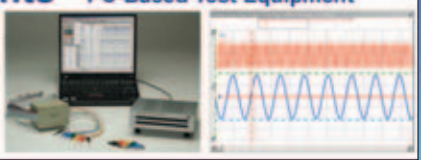

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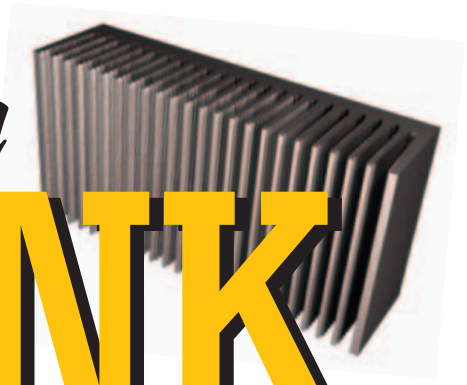
Choosing a HEATSINK



— by H. Ward Silver

Let's face it — if this article was titled, "Thermal Analysis," you might put off reading it! But choosing a heatsink? Everybody understands what that's all about, right? To make that choice, you have to do a little thermal analysis (gotcha!), but if you can do Ohm's Law, you already know how!

Introduction

Any time current flows through a conductor, energy must be dissipated in the form of heat with the power — $P_d = I^2R$. (For superconductors, R = 0.) It's also true that when a voltage drop and current flow exist at the same time — $P_d = V \times I$. Heating from current flow is present everywhere in an electrical circuit, but by far most of the heat is generated within electronic components.

An electrical component gets rid of heat by transferring it to the surrounding air. The heat can pass directly to the air from the surface of the component or a heatsink can be used. Either way, if too much heat builds up, the component can be damaged. Most of the time, only a few components have a heavy heat load — pass transistors, driver ICs, solenoids. Nevertheless, you're the circuit designer, so you're responsible for figuring out which components need to be cooled and how to do it.

Heat Transfer = Ohm's Law

The flow of heat follows rules that are remarkably similar to those that govern the flow of electric current. As Figure 1 shows, temperature difference (ΔT) takes the place of voltage and heat flow (P) takes the place of current. The new symbol — θ — represents thermal resistance, analogous to electrical resistance; something you're already quite familiar with. The fundamental equation for heat transfer looks just like Ohm's Law:

$$\Delta T = T_a - T_b = T_{ab} = P \times \theta_{ab}$$

T acts as a "heat voltage," P like a "heat current," and θ_{ab} as "heat resistance." T is usually specified in °C and P in watts. θ is specified in °C/W, which looks a little strange until you consider that resistance is really "volts per amp." As more power flows through a thermal resistance, the temperature drop across it increases; 'a' and 'b' are two physical locations and the heat flow occurs between them.

What happens if several different thermal resistances are encountered by the heat flow? Just like electrical resistance, the thermal resistances sum in series. The total thermal resistance is $\theta = \theta_1 + \theta_2 + \ldots + \theta_n$. Temperatures at the junction of the

FIGURE 1. Basic heat transfer is very similar to Ohm's Law for resistance.

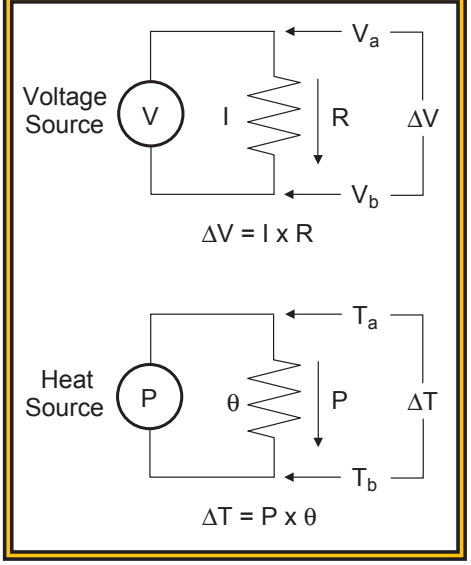


FIGURE 2. If the heat must flow through a sequence of materials, then the thermal resistance of each material sums together, just as electrical resistors in series do.

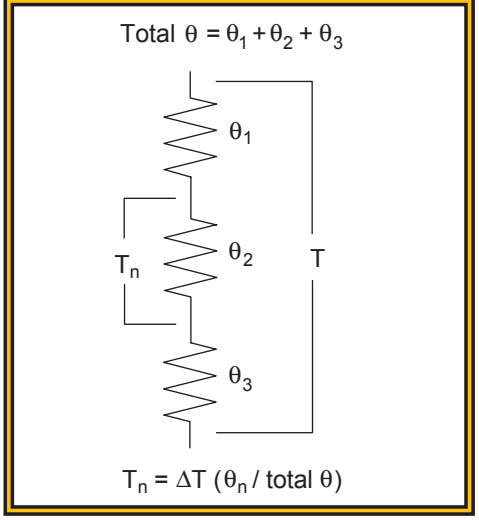


TABLE 1
Heat Generation in Common Electronic Components

- Resistor — $P_d = I^2 \times R = V^2 / R = V \times I$
- Diode, SCR, or TRIAC — $P_d = V_f \times I_{avg}$ where V_f is forward voltage drop and I_{avg} is average forward current
- Transistor — $P_d = V_{CE} \times I_C$ (bipolar) $P_d = V_{GS} \times I_D$ (FET)
- Inductor, Capacitor, Transformer — $P_d = I^2 \times R_{LOSS}$
- Solenoid or Relay — $P_d = I^2 \times R_{COIL}$

thermal resistances can be calculated just like voltages in a voltage divider, as shown in Figure 2. (Yes, there are parallel heat circuits, too.)

The discrete thermal resistances in series represent the flow of heat through a series of materials. For example, in winter, the heat in your house flows first through the air inside, then through the inner wall, through the insulation, and through the outer wall to the ambient air outside. The larger the total thermal resistance, the less heat is lost for any given combination of inside and outside temperatures. Conversely, if you like the temperature high or it gets colder outside, you'll lose more heat because ΔT is larger.

How Much Heat Does a Component Generate?

Power dissipation in resistors is pretty easy to calculate, but what about semiconductors and ICs? For components where the resistance isn't known or changes — such as for an FET — you can't easily use I^2R. In these cases, use V x I. And that works for resistors, too! Table 1 shows a list of equations for heat generation in some common electronic components.

If a resistor is carrying AC current, use RMS values for voltage and current. For either DC or AC currents that are intermittent, multiply P_d by the duty factor of the current. For example, if a resistor only carries current in pulses that are on one-tenth of the time, multiply P_d by 0.1.

For semiconductors, you'll have to figure out the average current flow and voltage. This can seem daunting in AC circuits, but there is a shortcut that overstates the heat load, leading to a conservative design. For example, let's estimate the heat dissipation in a rectifier that is on for one half-cycle and off for the other half-cycle. Multiply the peak current by the maximum forward voltage — this assumes full heat generation whenever the diode is conducting — then divide by two to account for the 50% duty factor.

This overstates the actual amount of heat generated, which reaches the maximum value at the peak of the current, but is less at other times. If you design for the estimated heat load, your components will run much cooler. Heating in other AC circuits can be estimated in similar fashion.

For estimating an IC's power dissipation, total the power dissipation from each significant source of heat — usually the output circuits. Calculate the power assuming the IC output is a transistor. Don't forget to include power dissipated by the IC's other circuitry — multiply the power supply voltage times current drawn by the IC.

Does Your Device Need a Heatsink?

Resistors and capacitors generate heat throughout or along their bodies. They are rated for some maximum continuous power dissipation (P_{dmax}) such as for a half-watt resistor. P_{dmax} is also specified at a specific ambient temperature because that determines the temperature at one end of the component's thermal resistance string.

Diodes and transistors generate heat in the very small volume of the junctions or channels that conduct current. This is generally referred to as the "junction" and is abbreviated as 'j.' Thermal resistance in these components from the heat-generating junction to the surrounding — or ambient conditions — is written as θ_{ja}.

This is sometimes referred to as the free-air thermal resistance because it represents the total thermal resistance between the junction and the ambient air, including all of the intervening package and mounting material.

Components made from semiconductors such as silicon or gallium arsenide must be kept cooler than some maximum temperature (T_{jmax}) or the device will be destroyed by melting or damaged by having its internal structures overheat and diffuse or migrate. For devices made from silicon, the maximum temperature is 125 to 150 °C.

To determine what the maximum temperature inside a device will be, start by looking up θ_{ja} in the device's data sheet and calculating how much power it will be dissipating during use. The junction temperature will be:

$$T_j = T_{ambient} + P \times \theta_{ja}$$

If you find T_j will be less than T_{jmax}, then no heatsink is needed. Be careful when selecting your ambient temperature. Inside an equipment enclosure, the actual ambient temperature at the surface of the component may be quite a bit higher than room temperature. You must also include a safety factor — 25 percent or 35 °C is often used.

Let's say that you find your device's T_j to be too close to the limit. Either P or θ_{ja} must be reduced. To reduce P, you'll have to change the circuit design. If you decide to reduce θ_{ja}, you'll have to figure out how to pass heat more effectively through the component's outer surface.

You must now split θ_{ja} into two thermal resistances in series: θ_{jc} — the thermal resistance from the junction to the outer surface (which you can't change) and θ_{ca} — from the case to ambient (which you can change). θ_{jc} is the thermal resistance from the junction to the case of the transistor,

which might be a metal tab or just the external plastic surface. This is illustrated in Figure 3.

Picking a Heatsink

One way to cool a component is by moving air across its surface, keeping $T_{ambient}$ low. You can use a fan or even orient the component so that natural convection keeps air moving across the hot surface. This technique is limited to power dissipation of about one watt or less, particularly in small components that have small surfaces.

For larger amounts of heat, a heatsink is required to lower θ_{ca}. Heatsinks can be anything sufficiently massive and thermally conductive to conduct heat away from the component. Almost any metal object can be used as a heatsink, including printed circuit board ground planes and the equipment chassis. You don't have to use a manufactured heatsink!

Semiconductors that are intended to dissipate heat have packages designed for use with a heatsink. For example, in the TO-220 package, the semiconductor sits directly on a metal tab that is electrically connected to the device. The TO-3 package is completely metal and is also electrically connected to the device inside. Why electrically connected? To avoid an intervening layer of material that would increase thermal resistance. The aggravation of having a non-isolated package is well worth the improved heat transfer efficiency.

The heatsink's thermal resistance in °C/W tells you how much the surface temperature (not the junction temperature) of the attached component will rise per watt of heat. Assume that this is a value based on a natural convection figure. Using a fan lowers the heatsink's thermal resistance. High power heatsinks will have values of θ_{ca} that are specified for different amounts of air flow.

To select a heatsink, start by specifying a maximum junction temperature. Calculate the amount of power the component will dissipate. Since θ_{jc} is fixed, calculate maximum case temperature:

$$T_{cmax} = T_{jmax} - P \times \theta_{jc}$$

Estimate the ambient temperature. The required thermal resistance of the heatsink is then:

$$\theta_{ca} = (T_{cmax} - T_{ambient}) / P$$

From the catalogs or websites of heatsink manufacturers, you can now select a heatsink that has both the right θ_{ca} and fits in your enclosure.

An Example of Heatsink Selection

A common heatsink application is dissipating heat from a pass transistor or voltage regulator, such as the common 7805. (Download the 7805 data sheet from **www.datasheetarchive.com**) Let's say the 7805 will drop the input voltage from 12V to 5V at its output with a peak sustained current load of 0.5 amps. We'll also assume that the inside of the electronics enclosure will be 33 °C or 10 °C higher than room temperature of 23 °C.

• Start by calculating total heat dissipation: $P_D = (V_{IN} - V_{OUT}) \times I = 7V \times 0.5 A = 3.5 W$. Without a heatsink, this regulator will get mighty toasty!

• Look up the 7805 junction to case thermal resistance: Codi Electronics specifies it as $R_{j-c} = 5$ °C/W.

• If we set maximum junction temperature at 80 °C, then $T_{cmax} = T_{jmax} - P \times \theta_{jc} = 80 - 3.5 \times 5 = 62.5$ °C.

• The heatsink's thermal resistance must be no larger than $\theta_{ca} = (T_{cmax} - T_{ambient}) / P = (62.5 - 33) / 3.5 = 8.4$ °C/W.

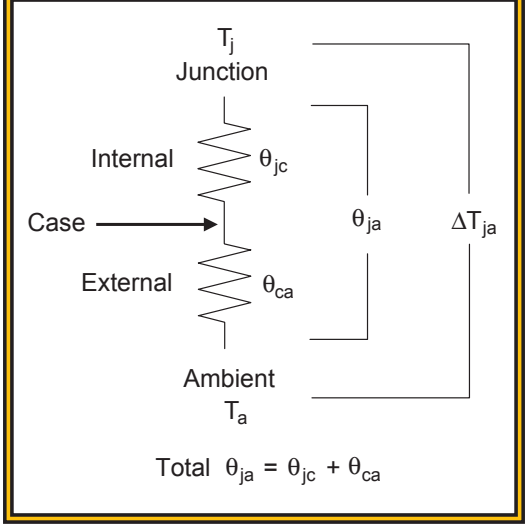
• Browsing the Digi-Key selection of heatsinks (**www.digikey.com**), I found that the IERC 7-340-2PP-BA is a nice choice, with a 7 °C/W rating. The margin of 1.4 °C/W also allows for a small additional amount of thermal resistance in the insulating pad required between the IC and heatsink.

You might decide that the heatsink is too big (it's about a cubic inch) or too expensive (single quantities are $1.75). In that case, you must allow a higher junction temperature or figure out how to reduce the power dissipation in the regulator. You could also lower the ambient temperature. Any of these three will allow you to use a heatsink with a higher thermal resistance. If you'd like more information on heatsink selection, heatsink manufacturer Aavid-Thermalloy has published a short tutorial on picking heatsinks at **www.aavidthermalloy.com/technical/papers/semisize.shtml**

Summary

That's the basic process: Figure your heat load, specify the maximum temperature, determine the thermal resistances involved, and go shopping! Eventually, you'll become skilled at managing heat — both in reducing its generation and in getting rid of it. And you can chalk it all up to thermal analysis. **NV**

FIGURE 3. Total device thermal resistance includes internal and external resistance.



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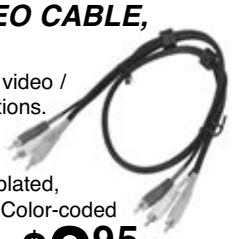

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Grayhill #70YY14350. In-line solid-state relay. Output, 1 Amp / 120 Vac. Input not listed on part, but appears to be the typical 3-32 Vdc control voltage. 1.52" x 0.68" x 0.18" thick. UL.

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Wintek# WDC2401P-1GNNA. Module size: 4.25" x 0.79" x 0.3" Display size: 3.5" x 0.4" Built-in driver. 14 pin male header, pins on 0.05" centers. Includes hook-up diagram.

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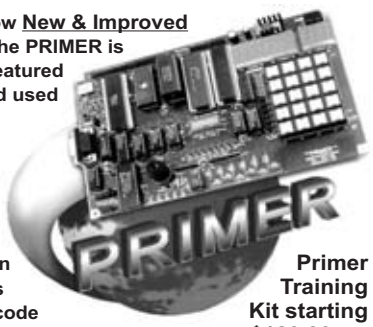

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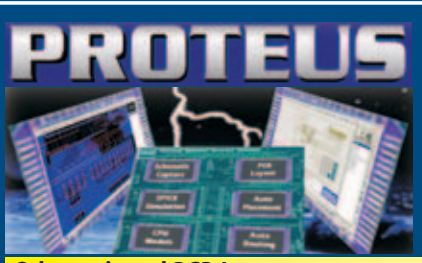

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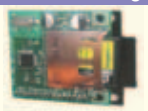

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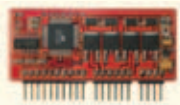

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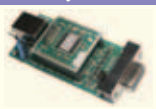

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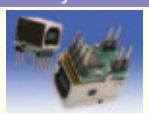

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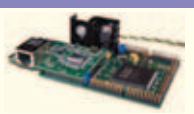

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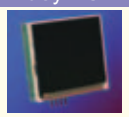

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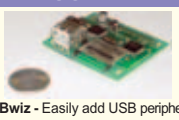

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UNDERSTANDING
Digital Logic ICs

PART 1 — Digital Logic IC Basics

Ray Marston explains digital logic IC fundamentals in this opening episode of a four-part, introductory mini-series.

BY RAY MARSTON

Modern digital logic ICs are widely available in three basic types: TTL devices (typified by the 74LS00 logic family), "slow" CMOS devices (typified by the "4000" logic family), and "fast" CMOS devices (typified by the 74HC00 and 74AC00 logic families). Each of these families has its own particular advantages and disadvantages, and its own special set of usage rules.

This four-part mini-series explains the basic principles and usage rules of each of these three digital logic families, and provides practical usage guidance for the vast range of ICs available in each of these families. This opening article concentrates on digital logic IC basics.

Digital Logic IC Basics

An IC can be described as a complete electronic circuit or "electronic building block," integrated into one or more semiconductor slices (or "chips") and encapsulated in a small, multi-pin package. An IC can be made fully functional by wiring it to a suitable power supply and connecting various pins to appropriate external input, output, and auxiliary networks.

ICs come in both "linear" and "digital" forms. Linear ICs are widely used as pre-amplifiers, power amplifiers, oscillators, and signal processors, etc., and give a basic output that is directly proportional to the magnitude (analog value) of the input signal, which itself may have any value between zero and some prescribed maximum limit.

One of the simplest types of linear IC elements is the unity-gain buffer. If a large sine-wave signal is connected to the input of this circuit, it produces a low-impedance output of almost identical form and amplitude, as shown in Figure 1(a). Digital ICs, on the other hand, are effectively blind to the precise amplitudes of their input signals, and simply recognize them as being in either a low or a high state (usually known as logic-0 and logic-1 states, respectively).

Their outputs similarly have only two basic states, either low or high (logic-0 or logic-1). One simple type of digital IC element is the non-inverting buffer. If a large sine-wave signal is connected to the input of this circuit, it produces an output that (ideally) is of purely digital form, as shown in Figure 1(b).

Digital ICs are available in a variety of rather loosely defined categories such as memory ICs, electronic delay-line ICs, and microprocessor support ICs, etc., but the most widely used category is that known as the "logic" type, in which the ICs are designed around fairly simple logic circuits such as digital buffers, inverters, gates, or flip-flop elements. Digital logic *circuits* come in a variety of basic types and can be built using a variety of discrete or integrated technologies. Figures 2 through 7 show a selection of very simple logic circuits that are designed around discrete components.

Figure 2(a) shows a simple inverting digital buffer (also known as a NOT logic gate), consisting of an unbiased transistor wired in the common-emitter mode, and Figure 2(b) shows the international symbol that is used to represent it. The arrowhead indicates the direction of signal flow, and the small circle on the symbol's output indicates the inverting action.

The circuit action is such that Q1 is cut off (with its output high) when its input is in the zero state and is driven fully on (with its output pulled low) when its input is high. This information is presented in concise form by the Truth Table of Figure 2(c), which shows that the output is at logic-1 when the input is at logic-0, and vice versa.

Figure 3(a) shows a simple non-inverting digital buffer, consisting of a direct coupled pair of common-emitter (inverter) transistor stages.

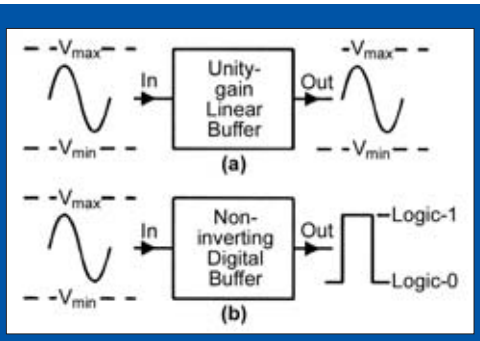


FIGURE 1. When a large input sine wave is fed to the input of a linear buffer (a), it produces a sine-wave output, but when fed to the input of a digital buffer (b), it produces a purely digital output.

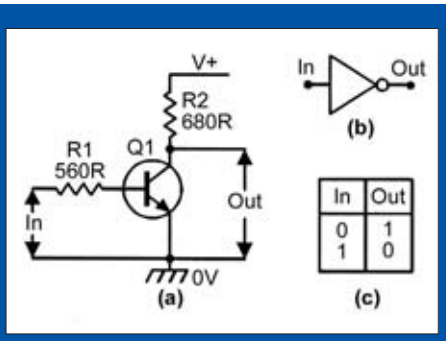


FIGURE 2. Circuit (a), symbol (b), and Truth Table (c) of a simple inverting digital buffer.

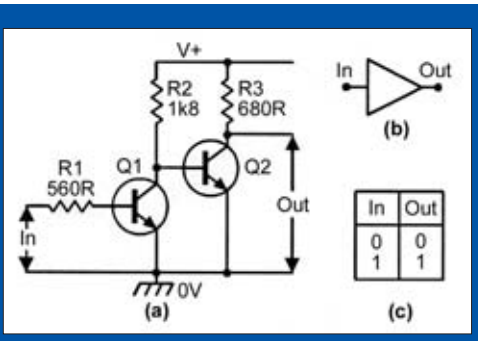


FIGURE 3. Circuit (a), symbol (b), and Truth Table (c) of a non-inverting digital buffer.

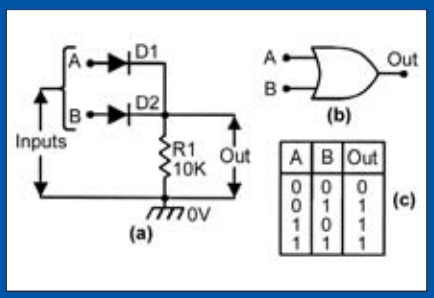


FIGURE 4. Circuit (a), symbol (b), and Truth Table (c) of a simple two-input OR gate.

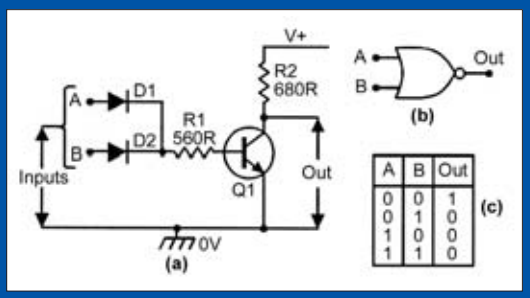


FIGURE 5. Circuit (a), symbol (b), and Truth Table (c) of a two-input NOR gate.

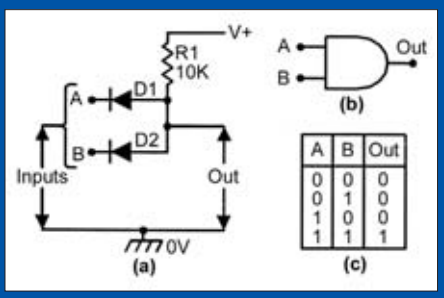


FIGURE 6. Circuit (a), symbol (b), and Truth Table (c) of a simple two-input AND gate.

Figure 3(b) shows the arrow-like international symbol used to represent it. Figure 3(c) shows the Truth Table that describes its action, e.g., the output is at logic-0 when the input is at logic-0, and is at logic-1 when the input is at logic-1.

In digital electronics, a "gate" is a logic circuit that opens or gives an output (usually defined as a high or logic-1 state) only under a certain set of input conditions. Figure 4(a) shows a simple two-input OR gate, made from two diodes and a resistor, and Figure 4(b) shown the international symbol used to represent it. Figure 4(c) shows its Truth Table (in which the inputs are referred to as A or B). Note that the output goes to logic-1 if A *or* B goes to logic-1.

Figure 5 shows the circuit, symbol, and Truth Table of a two-input NOR (Negated-output OR) gate, in which the output is inverted (as indicated by the output circle) and goes to logic-0 if either input goes high.

Figure 6(a) shows a simple two-input AND gate, made from two diodes and a resistor, and Figure 6(b) shows its standard international symbol. Figure 6(c) shows the AND gate's Truth Table, which indicates that the output goes to logic-1 only if inputs A *and* B are at logic-1.

Finally, Figure 7 shows the circuit, symbol, and Truth Table of a two-input NAND (Negated-output AND) gate, in which the output is inverted (as indicated by the output circle) and goes to logic-0 only if both inputs are at logic-1.

Note that although the four basic types of logic gate circuits described here are each shown with only two input terminals, they can, in fact, be designed or used to accept any desired number of inputs, and can be used to perform a variety of simple logic operations. Many types of digital buffers and gates are readily available in IC form, as are many other digital logic circuits, including flip-flops, latches, shift registers, counters, data selectors, encoders, and decoders.

Practical digital ICs may range from relatively simple logic devices — housing the equivalent of just a few basic gates or buffers — to incredibly complex devices housing the equivalent of tens of thousands of interconnected gates, etc. By convention, the following general terms are used to describe the relative density or complexity of integration:

• *SSI (Small Scale Integration)* — Complexity level between one and 10 gates.

• *MSI (Medium Scale Integration)* — Complexity level between 10 and 100 gates.

• *LSI (Large Scale Integration)* — Complexity level between 100 and 1,000 gates.

• *VLSI (Very Large Scale Integration)* — Complexity level between 1,000 and 10,000 gates.

• *SLSI (Super Large Scale Integration)* — Complexity level between 10,000 and 100,000 gates.

Note that most logic ICs of the types described throughout this series of articles have complexity levels ranging from four to 400 gates, and are thus SSI, MSI, or LSI devices. In broad terms, most microprocessor ICs and moderately large memory ICs are VLSI devices, while large dynamic

RAM (Random Access Memory) ICs are SLSI devices.

Digital Waveform Basics

Digital logic ICs are invariably used to process digital waveforms. It is thus pertinent at this point to review some basic facts and terms concerning digital waveforms.

Waveforms are available in either square or pulse form. Figure 8 illustrates the basic parameters of a square wave. In each cycle, the wave first switches from zero to some peak voltage value (Vpk) for a fixed period, then switches low again for a second fixed period, and so on. The time for the waveform to rise from 10% to 90% of Vpk is known as its *rise time*, and the time for it to drop from 90% to 10% of Vpk is known as its *fall time*.

In each square-wave cycle, the high part is known as its *mark* and the low part as its *space*. In a symmetrical square wave such as the one in Figure 8, the mark and space periods are equal. Such waveforms are said to have a 1:1 Mark-Space (or M-S) ratio, or a 50% duty cycle (since the mark duration forms 50% of the total cycle period). Square waves are not necessarily symmetrical, but are always free-running or repetitive, i.e., they cycle repeatedly, with consistent mark and space periods.

A pulse waveform is a bit like a square wave. It has both rise and fall times, but only one portion — either its mark or its space period — is specified; the duration of the remaining period is unimportant. Figure 9(a) shows a basic "positive-going" pulse waveform, which has a 'rising' or positive-going leading edge, and Figure 9(b) shows a "negative-going" pulse waveform, which has a "falling" or negative-going leading edge. Note that many modern MSI digital ICs, such as counter/dividers and shift registers, can be selected or programmed to trigger on either the rising or the falling edge of an input pulse, as desired by the user.

If a near-perfect pulse waveform is fed to the input of a real-life amplifier or logic gate, etc., the resulting output waveform will be distorted both in form and time, as shown in Figure 10. Thus, not only will the output waveform's rise and fall times be increased, but the arrival and termination of the output pulse will be time delayed relative to that of the input pulse.

The mean value of the delays is called the device's *propagation delay*. Also, the peaks of the waveform's rising and falling edges may suffer from various forms of ringing, overshoot, undershoot, etc. The magnitudes of these distortions vary with the quality or structure of the amplifier or gate.

In practice, pulse input waveforms may sometimes be so imperfect that they may need to be "conditioned" before they are suitable for use by modern, fast-acting digital ICs. Specifically, they may have such long rise or fall times that they may have to be sharpened up via a Schmitt trigger before they are suitable for use.

Again, many mechanically-derived pulse waveforms, such as those generated via switches or contact-breakers, may suffer from multiple "contact bounce" problems such as those shown in Figure 11(a). In this case, they will have to be converted to the clean form shown in Figure 11(b) before they can be usefully used.

Logic Families

Practical digital logic circuits and ICs can be built using various technologies. The first successful family of digital logic ICs appeared in the mid 1960s. These used a 3.6 V supply and employed a simple technology that became known as Resistor-Transistor Logic, or RTL. Figure 12 shows the basic circuit for a three-input RTL NOR gate. RTL was rather slow in operation, having a typical propagation delay (the time taken for a single pulse edge or transition to travel from input to output) of 40 nS in a low-power gate, or 12 nS in a medium power gate. RTL is now obsolete.

Another early type of IC logic technology, developed in the late 1960s, was based on simple developments of the discrete types of logic circuit shown in Figures 2 through 7, and was known as Diode-Transistor Logic, or DTL. Figure 13 shows the basic circuit of a three-input DTL NAND gate. DTL used a dual five-volt power supply, gave a typical propagation delay of 30 nS, and gave an output of less than 0.4 V in the logic-0 state and greater than 3.5 V in the logic-1 state. DTL is now obsolete.

Between the late 1960s and mid 1970s, several other promising IC logic technologies appeared. Most of them soon disappeared back into oblivion again. Amongst those that came and either went or receded in importance were HTL (High Threshold Logic), ECL (Emitter Coupled Logic), and PML (P-type MOSFET Logic). The most durable of these technologies was ECL, which is still in production and gives very fast operation, but at the cost of very high current/power consumption.

Figure 14 shows the basic circuit of the ECL digital amplifier — a non-saturating emitter-coupled differential amplifier (Q1 and Q2) with emitter-

"An IC can be described as a complete electronic circuit or "electronic building block," integrated into one or more semiconductor slices (or "chips") and encapsulated in a small, multi-pin package."

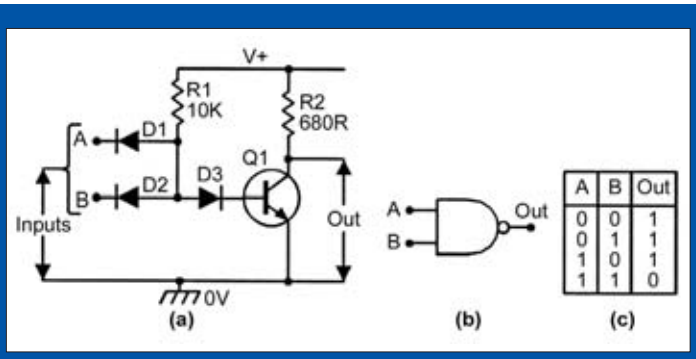


FIGURE 7. Circuit (a), symbol (b), and Truth Table (c) of a two-input NAND gate.

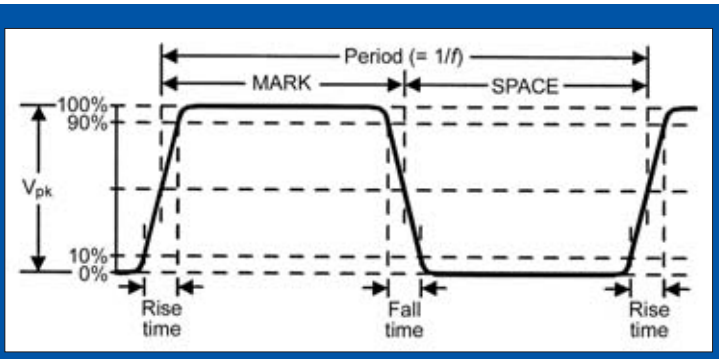


FIGURE 8. Basic parameters of a square wave.

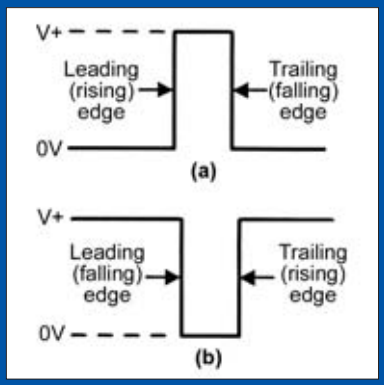


FIGURE 9. Basic forms of (a) "positive-going" and (b) "negative-going" pulses.

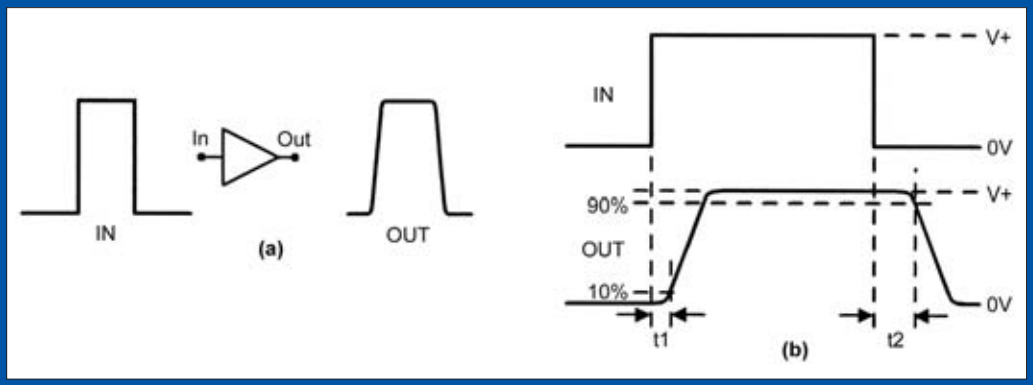


FIGURE 10. A perfect pulse, fed to the input of a practical amplifier or gate, produces an output pulse that is distorted both in form and time. The output pulse's time delay is called its propagation delay, and (in (b)) = $(t_1 + t_2) / 2$.

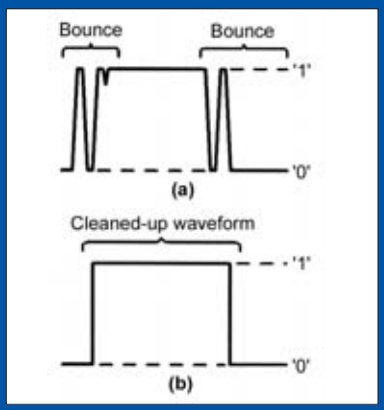


FIGURE 11. Mechanically derived pulse waveforms often suffer from contact bounce (a), and must be cleaned up (b) before use.

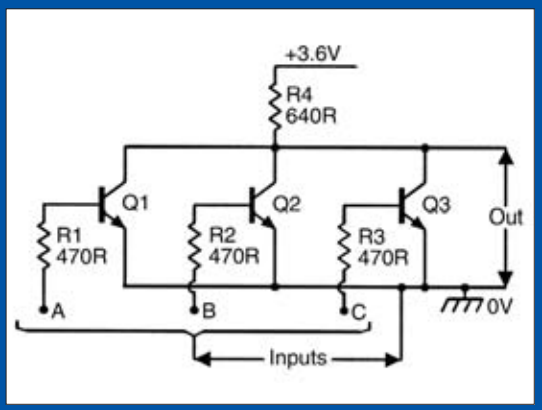


FIGURE 12. IC version of a three-input RTL NOR gate.

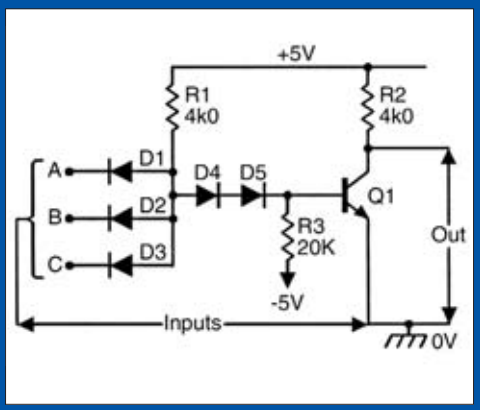


FIGURE 13. IC version of a three-input DTL NAND gate.

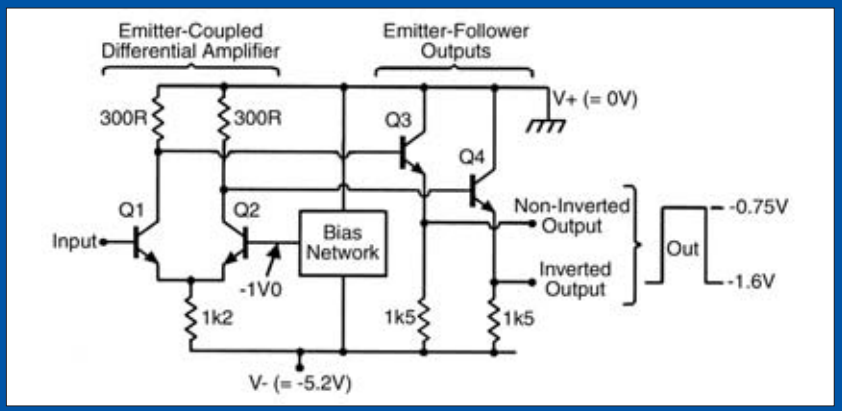


FIGURE 14. Basic ECL (Emitter-Coupled Logic) amplifier circuit.

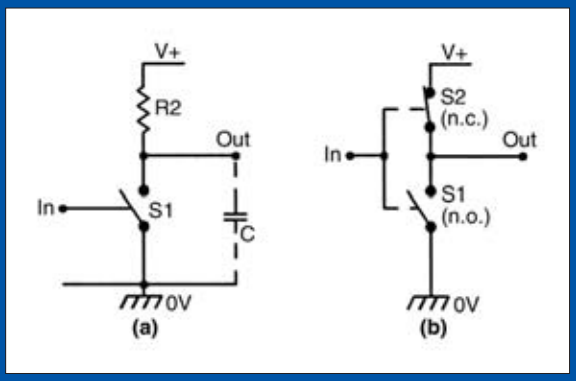


FIGURE 15. (a) Simple digital switch. (b) Basic "totem-pole" digital switch.

follower output stages (Q3 and Q4). Because its transistors do not saturate when switched, it gives typical propagation delays of only 4 nS. Note that the circuit's V+ line is normally grounded and the V- line is powered at -5.2 V.

Under this condition, the circuit provides nominal digital output swings of only 0.85 V, i.e., from a low state of -1.60 V to a high state of -0.75 V. The circuit's digital input is applied to the base of Q1. A non-inverted output is available on Q3 emitter, and an inverted output is available on Q4 emitter. Modern ECL ICs are used only when ultra high-speed operation is required.

The basic aim of digital IC designers during the late 1960s to early 1970s was to devise a technology that would be simple to use and that achieved a good compromise between high operating speed and low power consumption. The problem here was that conventional transistor-type circuitry, using an output stage of the Figure 2 type (as in RTL and DTL systems), was simply not capable of meeting the last two of these design needs. The essence of this problem — and its ultimate solution — can be understood with the aid of Figure 15.

Figure 15(a) shows a simplified version of the circuit in Figure 2, with Q1 replaced by a mechanical switch. Remember here that all practical output loads inevitably contain capacitance (typically up to about 30 pF in most digital circuits), so it can be seen that this basic circuit will charge (source current into) a capacitive load fairly slowly via R2 when S1 is open, but will discharge it (sink current from it) rapidly via S1 when S1 is closed; thus, circuits of this type produce digital outputs that tend to have long rise times and short fall times. The only way to reduce the rise time is to reduce the R2 value, and that increases S1's (Q1's) current consumption by a proportionate amount.

Note that one good way of describing the deficiency of the Figure 15(a) logic circuit is to say that its output gives an active pull-down action (via S1), but a passive pull-up action (via S2). Obviously, a far better digital output stage could be made by replacing R2 and S1 with a ganged pair of change-over switches, connected as shown in Figure 15(b), so that S2 gives active pull-up action and S1 gives active pull-down action, but so arranged that only one switch can be closed at a time (thus ensuring that the circuit consumes zero quiescent current). Such a circuit — with one electronic switch placed above the other — is called a *totem-pole* output stage.

Throughout the late 1960s, digital engineers strove to design a cheap and reliable electronic version of the totem-pole output stage, and then — in the early 1970s — they hit the jackpot. Two such technologies hit the commercial market like bombshells and went on to form the basis of today's two dominant digital IC families. The first of these — based on bipolar transistor technology — is known as TTL (Transistor-Transistor Logic). TTL is the basis of the so-called "74" family of digital ICs that first arrived in 1972.

The second, based on FET technology, is known as CMOS (Complementary *MOS*-FET logic). CMOS is the basis of the rival "4000-series" (and the similar "4500-series") digital IC family that first arrived in about 1975. The TTL and CMOS technologies have vastly different characteristics, but both offer specific technical advantages that make them invaluable in particular applications.

The most significant differences between the technologies of CMOS and TTL ICs can be seen in their basic inverter/buffer networks, which are used (sometimes in slightly modified form) in virtually every IC within the family range of each type of device. Figures 16 and 17 show the two different basic designs.

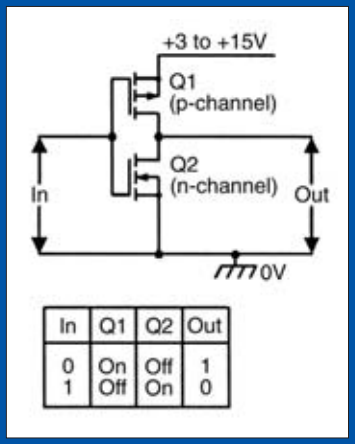
The CMOS inverter of Figure 16 consists of a complementary pair of MOSFETs, wired in series, with p-channel MOSFET Q1 at the top and n-channel MOSFET Q2 below, and with both high-impedance gates joined together. The pair can be powered from any supply in the 3–15 V range. When the circuit's input is at logic-0, the basic action is such that Q1 is driven on and Q2 is cut off, and the output is actively pulled high (to logic-1). Note that the output can source (drive) fairly high currents into an external load (via Q1) under this condition, but that the actual inverter stage consumes near-zero current, since Q2 is cut off.

When the circuit's input is at logic-1, the reverse of this action occurs: Q1 is cut off and Q2 is driven on, and the output is actively pulled low (to logic-0). Note that the output can sink (absorb) fairly high currents from an external load (via Q2) under this condition, but that the actual inverter stage consumes near-zero current, since Q1 is cut off.

Thus, the basic CMOS inverter can be used with any supply in the 3-15 V range, has a very high input impedance, consumes near-zero quiescent current, has an output that switches almost fully between the two supply rails, and can source or sink fairly high output load currents. Typically, a single basic CMOS stage has a propagation delay of about 12-60 nS, depending on supply voltage.

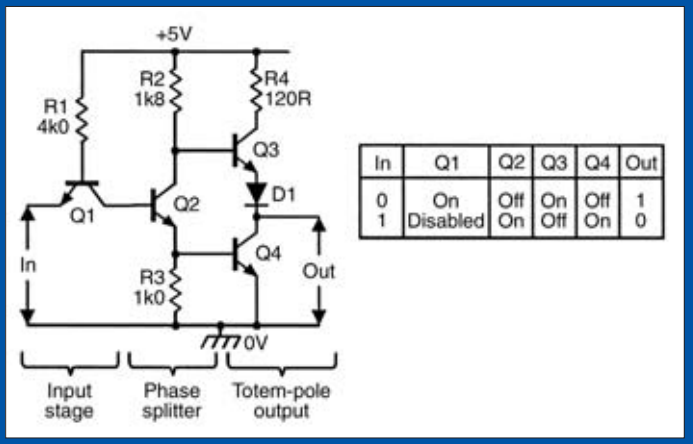
The TTL inverter of Figure 17 is split into three sections, consisting of an emitter-driven input (Q1), a phase-splitter (Q2), and a totem-pole output stage (Q3-D1-Q4). It must be powered from a five-volt supply. When the circuit's input is pulled down to logic-0, the basic action is such that Q1 is saturated, thus depriving Q2 of base current and causing Q2 and Q4 to cut off, and, at the same time, causing emitter-follower Q3 to turn on via R2 and give an active pull-up action in which the output has (because of various volt-drops) a typical loaded value of about 3.5 V.

This circuit can source fairly high currents into an external load. Conversely, when the circuit's input is at logic-1, Q1 is disabled, allowing Q2 to be driven on via R1 and the



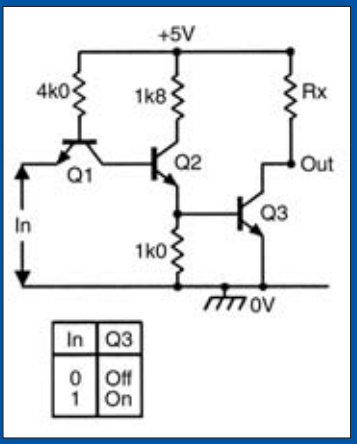
In	Q1	Q2	Out
0	On	Off	1
1	Off	On	0

FIGURE 16. Circuit and Truth Table of a basic CMOS inverter.



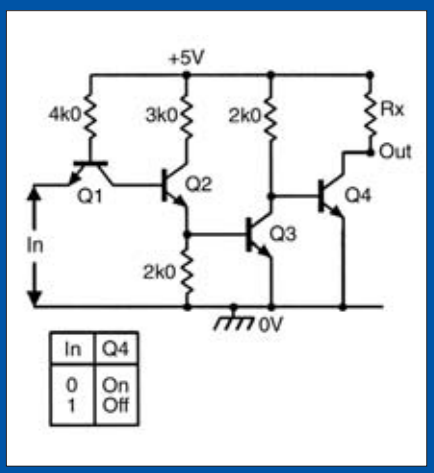
In	Q1	Q2	Q3	Q4	Out
0	On	Off	On	Off	1
1	Disabled	On	Off	On	0

FIGURE 17. Circuit and Truth Table of a basic TTL inverter.



In	Q3
0	Off
1	On

FIGURE 18. TTL inverter with open-collector output.



In	Q4
0	On
1	Off

FIGURE 19. TTL non-inverting buffer with open-collector output.

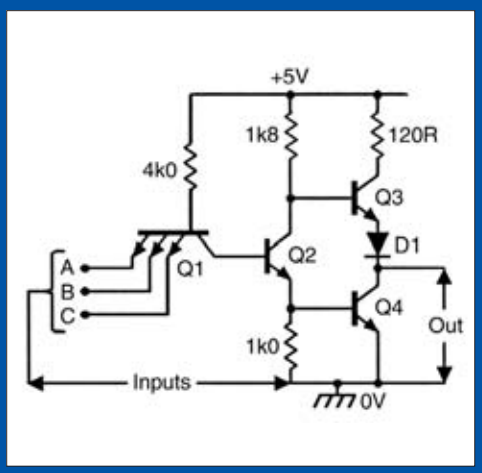


FIGURE 20. TTL three-input NAND gate.

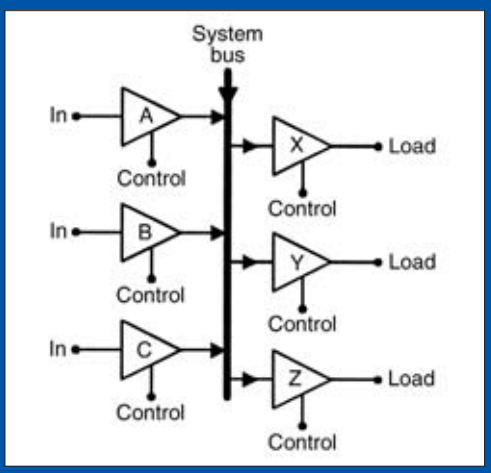


FIGURE 21. Tri-State logic enables several outputs or inputs to be connected to a common bus. Only one output/input must be made active at any given moment.

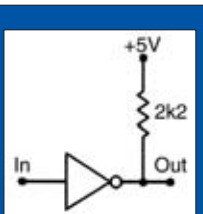


FIGURE 22. An external 2 kΩ pull-up resistor connected to the output of a totem-pole stage pulls the output to almost +5 V in the logic-1 state.

forward-biased base-collector junction of Q1, thus driving Q4 to saturation and simultaneously cutting off Q3.

Under this condition, Q4 gives an active pull-down action and can sink fairly high currents, while the output takes up a typical loaded value of 400 mV. Note that (ignoring external load currents) the circuit consumes a quiescent current of about 1 mA in the logic-1 output state, and 3 mA in the logic-0 output state.

Thus, the basic TTL inverter can only be used with a five-volt supply, has a very low input impedance, consumes up to 3 mA of quiescent current, has an output that does not switch fully between the two supply rails, and can source or sink fairly high load currents. Typically, a single basic TTL stage has a propagation delay of about 12 nS.

Basic TTL Circuit Variations

There are five very important variations of the basic Figure 17 TTL inverter circuit. The simplest of these is the so-called "open collector" TTL circuit, which is shown in basic form in Figure 18. Here, output transistor Q3 is cut off when the input is at logic-0, and is driven on when the input is at logic-1. Thus, by wiring an external load resistor between the OUT and +5 V pins, the circuit can be used as a passive pull-up voltage inverter that has an output that (when lightly loaded) switches almost fully between zero and the positive supply rail value.

Alternatively, it can be used to drive an external load (such as an LED or relay, etc.) that is connected between OUT and a positive supply rail, in which case the load activates when a logic-1 input is applied.

The second variation is the non-inverting amplifier or buffer. This is made by simply wiring an additional direct-coupled inverter stage between the phase-splitter and output stages of the standard inverter. Figure 19 shows an open collector version of such a circuit, which can be used with an external resistor or load. In this example, Q4 turns on when a logic-0 input is applied.

Figure 20 shows a major TTL design variation. Here, the basic inverter circuit is used with a triple-emitter input transistor, to make a three-input NAND gate in which the output goes low (to logic-0) only when all three inputs are high (in the logic-1 state). Multiple-emitter transistors are widely used within TTL ICs. Some TTL gates use an input transistor with as many as a dozen emitters to make a 12-input gate.

A further variation concerns the use of a "Tri-State" (or "three-state") type of output that incorporates additional networks plus an external ENABLE control terminal. In one state, the totem-pole output stage operates in its normal logic-0 or logic-1 mode, but in the other state, both totem-pole transistors are disabled (turned off), creating an open-circuit (high impedance) output. This facility is useful in allowing several outputs or inputs to be shorted to a common bus or line, as shown in Figure 21, and to communicate along that line by ENABLING only one output and one input device at a time.

The final circuit variation is an application one, and concerns the use of an external 2 kΩ pull-up resistor on a totem-pole output stage, as shown in Figure 22. This resistor pulls the output (when lightly loaded) up to virtually the full +5 V supply value when the output is in the logic-1 state, rather than to only +3.5 V. This is sometimes useful when interfacing the output of a TTL IC to the input of a CMOS IC, for example.

The "74 Series" Digital ICs

TTL IC technology first hit the electronics engineering scene in a big way in about 1972, when it arrived in the form of an entire range of digital logic ICs that were exceptionally easy to use. The range was an instant international success, and quickly became the world's leading IC logic system. Its ICs were produced in both commercial and military grades, and carried prefixes of 74 and 54, respectively; the commercial product range soon became known simply as the "74 series" ICs.

Over the years, the "74 series" ICs have progressively expanded their range of devices and advanced their production technology, so that today the 74 series is as popular and versatile as ever. When first introduced in the early 1970s, the series was based entirely on a simple type of TTL technology, but in later years, new sub-families of TTL were introduced in the series, and then various types of CMOS technology was added to it, so that today's 74 series incorporates a variety of TTL and CMOS sub-families. Next month, we will take a close look at the sub-families of 74 series ICs, and explain some basic TTL terminology. **NV**

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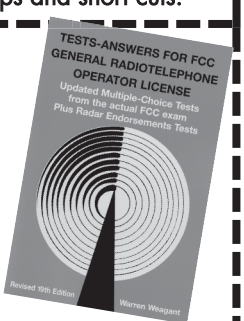
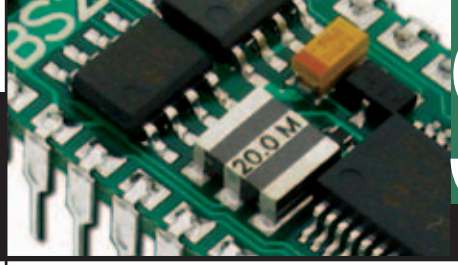




■ BY JON WILLIAMS

A TALE OF TWO PROPS
(Advanced BS1 Programming)

AFTER SPENDING A FEW MONTHS with Parallax's newest controller — the Propeller chip — why not step back in time a bit (13 years!) and work with the oldest, the venerable BS1 — the controller that started it all for Parallax. I recently noted that these days (with the Propeller) remind me of the first months of the BS — when everything was new, the rules had changed, and what wasn't possible yesterday suddenly was today. Of course, the BS1 has found new life as the core of the Prop-1 controller and, despite its low cost, many customers have asked for "more," that is, some actually want to control two props — independently — with one controller. Can we do it? Sure, but it will test our BS1 programming skills.

Here it is — the middle of summer. It's hot as Hades in many places and we're already talking about Halloween prop control. The truth is that real die-hards have been at it for a couple months now, and Parallax has attended and participated in several regional trade shows that attract Halloween prop builders. In fact, you can catch us this month in Columbus, OH, at the Midwest Haunters Convention. No doubt there will be lots of discussion on prop programming — we're actually doing a short seminar on the subject.

When we designed the Prop-1 after HauntX in 2005, we set the price at a point where we felt users could dedicate one controller per prop. Did that happen? Well, mostly, but there are those on a real serious budget that turned to us for guidance — they expressed a need to control two completely independent props with just a single Prop-1 controller.

One of our customers — a guy named Allan — had a bit of success, which was quite impressive for someone who hadn't spent a great deal of time with the BS1 — remember, PBASIC1 is not nearly as fancy as other flavors of BASIC. He and I exchanged ideas and it finally occurred to me that I could use tricks developed for a commercial product (BS2-based) to create a BS1-based multi-prop controller program.

THE KISS PROP PRINCIPLE

Most of the prop builders we work with are not hardcore programmers and really don't care to be, so they tend to stick with the KISS prop principle:

A) Activate an output.
B) PAUSE as required by the output.
C) Deactivate the output.

This works perfectly well for single-prop controls, but when we get into multiple props on one controller we're stepping it up a bit. In essence, we're creating and running multiple "threads" of program code. Of course, the Prop-1 is a very simple controller and I'm not suggesting for a millisecond that it's "multi-threaded." That said, we can employ techniques in high-level PBASIC that mimic "time-slicing" in more sophisticated systems.

DUAL-ACTION DEMOLITION

Controlling two sets of outputs simultaneously requires a different approach — we certainly can't allow one prop to be hung up on a **PAUSE** instruction while the other prop needs to change the output states of its I/O pins. So, Rule #1 is that **PAUSE** — for event timing — is out.

How, then, do we control the timing of the outputs? Some of you may remember a program we did a few years ago called a "drum

sequencer." This coding technique is the software analog a player piano; as the "sheet" is scrolled, events are picked up and "played."

We can create a play "sheet" (outputs sequence) in an EEPROM table and include the timing between events to control how quickly things move. The timing will actually control the duration between table reads, therefore, controlling the timing between possible output changes. So, Rule #2 of a dual prop controller on the BS1 is that events are table-driven.

Okay, how are we going to get some known timing element into the prop control? The answer is deceptively simple: use the trigger input check code to create a specific delay. In order to keep things really simple, I use 100 ms. Let's have a look:

```
Main:
  FOR loopTmr = 1 TO 5
    seq1 = seq1 | Trigger1
    seq2 = seq2 | Trigger2
    PAUSE 20
  NEXT
```

As you can see, this looks a bit different than our stock trigger-detection loop — usually such a loop waits until a trigger is present before dropping through. In this case, though, what the loop does is update (if a trigger input is present) one or both bit status flags (*seq1* and *seq2*) for the sequences. The loop always runs five times and, with a 20 ms **PAUSE** embedded in the loop, it takes just a bit longer than 100 ms to scan the inputs. This 100 ms delay will be used as our core timing element (we're going to keep things simple and ignore program overhead).

Let me take a small detour for a moment on a BS1 programming habit. When I write code for the BS1, I always start assigning variables at B2, leaving B0 and B1 available for future use. Why? Because these are the only two BS1 variables that allow bit-level access and — in this program — we need them. Since most BS1 programs are small and we generally have enough RAM, start your assignments at B2 so that you have the bits in B0 and B1 available if an update requires them.

Back to the program: Note that the OR operator is used in the trigger loop. The reason for this is that seq1 and seq2 denote the running state (1 is running, 0 is not running) of the respective sequences. By using the OR operator, we can start a sequence (0 OR 1 = 1), and if the sequence is already running, there is no change on a subsequent trigger input (1 OR 1 = 1). Note that the Prop-1 inputs pins — P6 and P7 — have been set to active-high, that is, their SETUP jumpers have been moved to the DN (pull-down) position.

TABLE MANNERS

Now things get a little bit heavy; our code has to slice-and-dice two sequence tables, dealing with each step in each table as independent entities. In the simplest terms, our program is doing this:

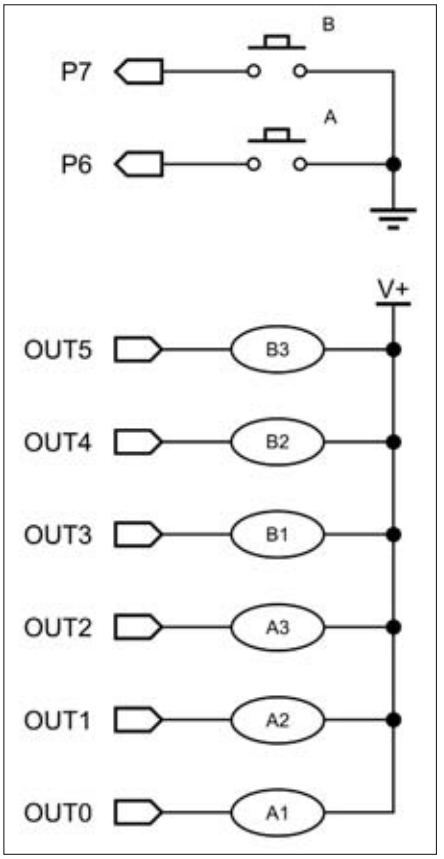
1) Timing/Trigger input loop
2) Process sequence 1 if running
3) Process sequence 2 if running

Steps 2 and 3 above are identical; the only difference being the pointer to the tables used and the escape destinations (Sequence 1 escapes to Sequence 2, Sequence 2 escapes back to Main). Since we're talking about tables, let's have a look at them as they're structured in the program:

```
SYMBOL   Seq1Start        = 0
SYMBOL   Seq1Mask         = %00111000

Sequence1:
  EEPROM (%00000001, 5)
  EEPROM (%00000010, 5)
  EEPROM (%00000100, 5)
  EEPROM (%00000010, 5)
  EEPROM (%00000001, 5)
  EEPROM (%10000000, 0)

SYMBOL   Seq2Start        = 12
SYMBOL   Seq2Mask         = %00000111

Sequence2:
  EEPROM (%00100000, 2)
  EEPROM (%00010000, 2)
  EEPROM (%00001000, 2)
  EEPROM (%10000000, 0)
```

Notice, too, that we're embedding some named constants in the table section; we don't normally do this but, for BS1-based table programs, it's a good idea as we have to assign these values manually; keeping the assignment code close is just handy, especially after changing the length of either of the tables.

For each sequence, we have a start value. This is the location in EEPROM where the actual table data starts. The



■ FIGURE 1. Dual Controller Connections.

second constant is a pins mask for the other sequence. This will be used for clearing the pins of one sequence without disturbing the pins under control by the other. Remember, this code is supposed to behave like two independent sequencers, so I/O pins are assigned to just one sequence and cannot be controlled by both.

Finally, each table entry consists of two bytes: the first is the outputs (with an end-of-sequence flag embedded in bit 7), and the second is the timing value, which is expressed in units of 100 ms (from the timing input loop).

Now for the nitty-gritty. Let's have a look at how the sequence processing works. This part of the program is divided into two sections: A) if sequence running and timer active, decrement timer, and B) load next step (outputs and timer).

Section A is labeled ***Run_X*** (X is 1 or 2) in the program. Here's the code:

```
Run_1:
  IF seq1 = Stopped THEN Run_2
    IF timer1 = 0 THEN Reload_1
      timer1 = timer1 - 1
      GOTO Run_2
```

Remember that with the BS1, we don't have IF-THEN-ELSE, so we're limited to IF-THEN-Address. This is not a programming problem, it just means that we have to be very deliberate in our design, often using what seems to be inverted logic. In this case, we want to update the timer if the sequence is running (seq1 = 1), so our first check is to see if it's stopped (seq1 = 0). If the sequence is stopped, then we blow right by the rest of this section and deal with sequence 2.

Let's say that the sequence is running and that we have time left for the current table entry. What we do is decrement the sequence timer value and then move on to the next sequence. Again, the timing delay is created at the trigger input loop so there is no need to put a **PAUSE** here.

When the sequence is running and the timer has expired, we will jump to the next part of the sequence processor: ***Reload_1***.

```
Reload_1:
  READ pntr1, pinsTemp
  PINS = PINS & Seq1Mask | pinsTemp
  pntr1 = pntr1 + 1
  READ pntr1, timer1
  pntr1 = pntr1 + 1
  IF endOfSeq = No THEN Run_2
    seq1 = Stopped
    pntr1 = Seq1Start
```

At ***Reload_1***, we begin by reading the next table entry into *pinsTemp*. This is then sent to the outputs after ANDing the current pin's state with the protection mask. Just for clarification, the mask for sequence 1 is designed to protect the pins for sequence 2 (and vice-versa). With the pins updated, the record pointer is incremented to point to the timing for this step. This gets read into *timer1* and the pointer is incremented a second time to point to the next table entry.

If this is not the end of the sequence, the program will make its way back to the top and the timer will be updated in the ***Run_1*** section. If you look closely at the last entry in each table, you'll see that the pin's output value has bit 7 set. This is used as the end-of-sequence indicator. Since *pinsTemp* is assigned to B1, the variable *endOfSeq* is aligned in BIT15 (bit 7 of B1, which we've aliased to make the program easier to follow).

If *endOfSeq* is 1, the program will clear the status variable — *seq1* — and then reset the table pointer — *pntr1* — back to the beginning. The code for sequence 2 is identical; the only difference being that it has jumps back to the top of the program at ***Main***.

And there you have it — on a tiny little Prop-1 controller we have the ability to control two props, completely independent of each other. And you thought it took a big PC to do time-slicing! Okay, I'm exaggerating a bit, but that is in essence what we're doing.

EVEN FARTHER?

Believe it or not, we can go even farther with this technique, but we'll save that for another day. I have actually written a program that will control two sequences and can use the Prop-1 outputs, as well as an RC-4 for AC outputs (lights, etc.). The program works, but it's a bit of a bear and, with all the code to manage parallel and RC-4 outputs, it doesn't leave a lot of room left for sequence tables.

Okay, gang, Halloween is not that many months away, so start your code writing now — and if you're in a budget pinch, you can double-up your Prop-1. And if you're in the Columbus, OH area this month, come by the Midwest Haunters Convention and say hello to John Barrowman and me. We'll have a booth there and love to meet new friends.

Until next time, Happy Stamping. **NV**

JON WILLIAMS
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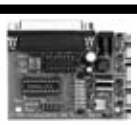

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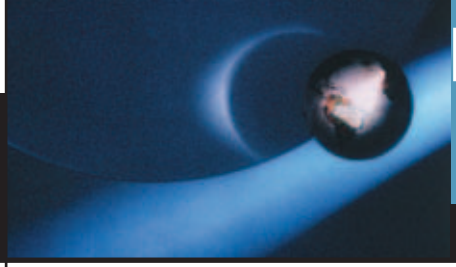


■ BY L. PAUL VERHAGE

THE NEAR SPACE GEIGER COUNTER TELESCOPE — Part 2

THIS MONTH'S COLUMN wraps up the Geiger Counter Telescope (GCT) and discusses a transistor experiment I performed. This article covers the GCT's field-of-view, a ground test of the GCT, and flight software that operates the GCT. There is a small note to clear up the RM-60 instructions in chapter eight of my near space book at the Parallax website and a transistor experiment which includes a competition for readers.

The GCT is launched on near spacecraft with a BASIC Stamp 2p based flight computer. With luck, its first flight will be NearSys 06A which takes place in Grand Island, NE. My plan is to eventually launch from every state, and Nebraska is one that is still on my list. You can read about the CNNSP at their website: **http://web pages.charter.net/kc0mwm/home**

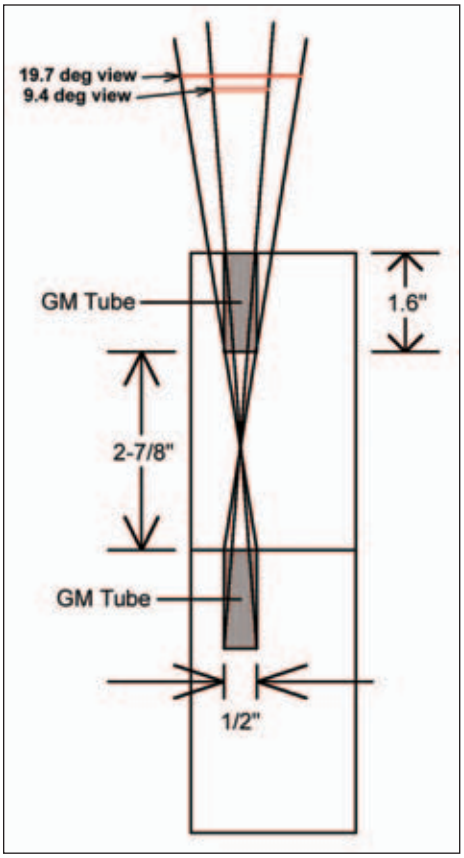
GCT RESOLUTION

What's the field-of-view of the GCT? Here are the pertinent measurements needed to calculate its field-of-view; the size of its Geiger-Muller (GM) tubes, and the distance between them.

In Figure 1, the rays shown passing through both GM tubes represent the cone of cosmic ray paths that will intersect both GM tubes. Cosmic rays traveling outside this cone will not be detected because they don't trigger a near simultaneous detection on both GM tubes. Note that I'm ignoring any cosmic ray flux from beneath the GCT since Earth should block cosmic rays approaching from below.

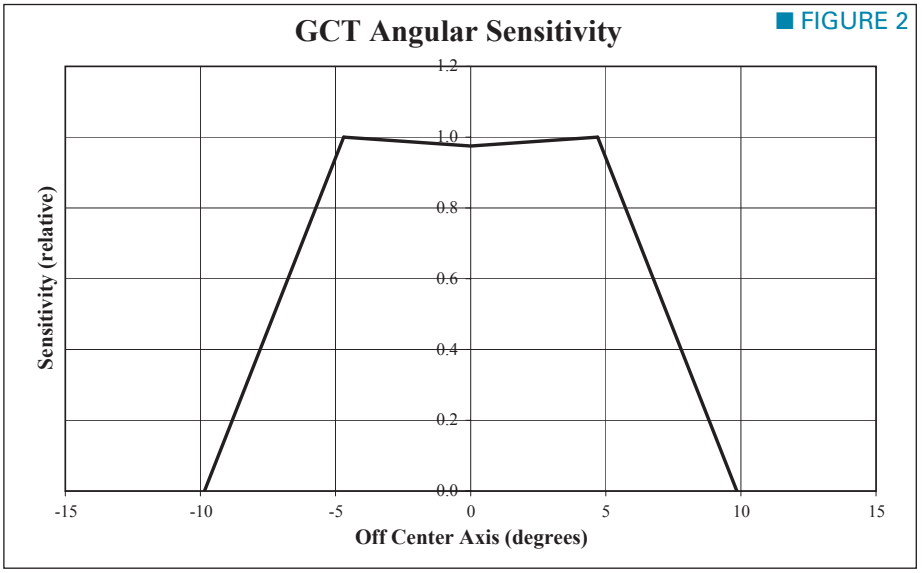
From this arrangement of GM tubes, I used trig to calculate that the GCT will only detect cosmic rays approaching within a 19.7 degree field-of-view. However, that 19.7 degree field-of-view is the GCT's maximum range and it represents any cosmic ray passing through any part of the two GM tubes, even through their outer edges.

The GCT is more likely to detect cosmic rays that pass through the maximum volume of the GM tubes (as opposed to just nicking their edges). So the GCT is more sensitive to cosmic



■ FIGURE 1. The physical arrangement of the GM tubes inside the GCT.

■ FIGURE 2



rays approaching within the central 9.4 degrees of its maximum field-of-view.

Just how sensitive the GCT is to cosmic rays depends on many factors. One is the distance a cosmic ray travels through the GM tubes. I've taken a stab at generating a sensitivity versus angle chart for the GCT, which is shown in Figure 2. The GCT sensitivity chart is based on the length of three paths through a GM tube. The three lengths are: passing straight down the middle of the GM tubes; through their top rims (the 9.4 degree cone); and through their bottom rims (the 19.7 degree rim). The sensitivity values are normalized (that is set to a value of 1.0) at the maximum sensitivity.

Note that the GCT sensitivity is very flat within 4.7 degrees of its central axis then drops off to zero in the next 5.15 degrees.

GCT GROUND TESTS

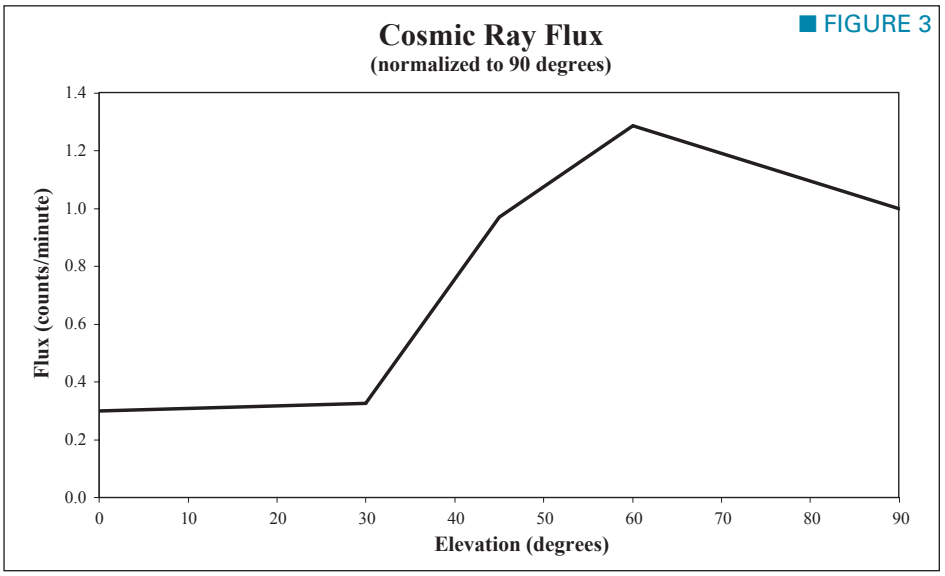
Using the Aware Electronics software — AW-SRAD — I ran a test of the GCT in my classroom in Boise, ID. The chart in Figure 3 was generated from over 18 hours of data. The cosmic ray flux was measured at angles of 0, 30, 45, 60, and 90 degrees above the horizon. Several runs were made to generate the data, which was combined in a single spreadsheet.

I'm not surprised the flux dropped off as the telescope approached an elevation of zero degrees, but I am puzzled by the peak at 60 degrees elevation. The tech center where I teach is a large brick and metal building, so that may be a factor. I'll run the test again outside some day and compare the results from the NearSys 06A flight. Expect to read the results some time this summer.

THE GCT SOFTWARE

The NearSys 06A mission will record cosmic ray counts for one minute intervals at the angles of 0, 45, and 90 degrees. The GCT PBASIC code orients the GCT, count pulses six times for 10-second intervals, combine the results, and then stores the results in non-volatile RAM. The process is then repeated at a different angle. Listing 1 shows the code I wrote for my BS2p-based flight computer.

■ FIGURE 3



The BS-2p in my flight computer can only record pulses for a maximum of around 18 seconds. For a single Geiger counter, this is acceptable, since a single Geiger counter has a field-of-view that encompasses the entire sky. For the GCT, this is way too short since the GCT has such a small field-of-view. So, my code counts cosmic rays for one minute by counting pulses for a 10-second interval and looping through the code six times. Each 10-second flux is added to the running total.

Experimental data collected during a flight is stored in a variable called workSpace. By calling a subroutine called Convert_Save_To SPRAM, the results of all the mission's experiments are stored in the BS-2p SPRAM. Then, at the conclusion of the mission's experiments, the properly-formatted results in SPRAM are moved into non-volatile RAM. This cycle of collecting data, storing (and formatting) it in SPRAM, and then moving the final

CLEARING UP SOME WIRING INSTRUCTIONS

In chapter eight of my near space book, I explained how to add a Geiger counter to a near spacecraft. My instructions for modifying the Geiger counter's RJ-11 jack are correct for one end of the cable, but it's not clear which end that is. So, let me try this again. It's easier to see the wires inside a RJ-11 jack if you look through the side of the plug without the tang. So we'll work from that side of the plug. Since the wires inside a phone cable don't switch around inside the cable, there are two different arrangements of wires you can see inside the RJ-11 jack. The arrangement will be one of these two.

Black, Red, Green, Yellow
Or
Yellow, Green, Red, Black

Remember, this is through the flat side of the RJ-11 jack, the side without the tang to get in the way. Which pattern of colored wires you see depends on which end of the phone cable you're looking at. So, before you begin cutting, make a note which color is the leftmost one. Now it's time to get to work.

Cut off the RJ-11 jack and strip back the outer jacket from its four wires. Leave the other end of the cable alone so it can still connect to the RM-60 Geiger counter. The exposed wires then are connected to the expansion port of your flight computer as described below. From left to right and looking at the flat side of the RJ-11 jack, the four colored wires have the following function.

- Leftmost (black or yellow) is ground
- Left of center (red or green) is +5V
- Right of center (green or red) is signal
- Rightmost (yellow or black) is not connected

I solder the wires to a male header, which is the standard interface for my near space program. The cosmic ray flux rate is determined by the PBASIC COUNT command since each RM-60 Geiger counter pulse (the RM-60 briefly goes from high to low) signifies the detection of a cosmic ray. The count is stored in memory along with the current GPS altitude.

■ FIGURE 4. The setup I used for this experiment.

record into NVRAM repeats through the entire flight.

After recovery, the results are retrieved with Stamp Plot Lite and copied into a spreadsheet for final processing. I'll show the entire process in a future column.

By the time you read this, I'll know how well the GCT works. Be sure to read about the results of the NearSys 06A mission at the CNNSP website listed previously.

A TRANSISTOR RESISTANCE EXPERIMENT

While engineering a cutdown device for near spacecraft, I performed an experiment with the 2N3904 transistor (which I use as a digital switch in different projects). In them, current from a microcontroller or timer saturates the transistor's base, completing a circuit's connection to ground. To design an efficient circuit that only uses as much current as necessary to saturate the transistor, I measured the resistance between the 2N3904's collector and emitter as a function of base current. I put the data into a spreadsheet to create a chart of the collector-emitter resistance and base current. The results were far more interesting than I thought they would be.

In this experiment, I varied the resistor controlling the current flow into the base of a 2N3904 NPN transistor, calculated the resulting base current, and measured the resistance between its emitter and collector with my digital multimeter (DMM).

The transistor's base current came from a wall-wart style power supply. To keep my calculations accurate, I measured the resistance of each resistor rather than relying on their printed values. The voltage output of the power supply varied a bit under load, so I also measured the power supply's voltage after every resistor change. The resistance between the transistor's emitter and collector was measured twice. The first time was with the DMM's common lead connected to the emitter and the positive lead connected to the collector. On the second measurement, the leads of the DMM were switched.

Measurements of the resistor's value, the power supply's voltage, and the transistor's two resistances went into a spreadsheet. The spreadsheet calculated the transistor's base current by dividing the power supply's voltage by the measured resistor value. A chart was created in the spreadsheet from the base current and transistor resistances.

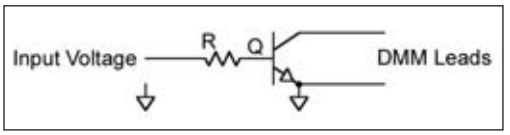
Notice that there's a knee in the transistor's emitter and collector resistance at around 3.5 mA of base current (the DMM common lead connected to the emitter). When the DMM leads were reversed, the knee occurred at 6 mA. So from that, I concluded that any base current

LISTING 1

```
GCT_Servo       CON  0          'gct servo on pin 0
GCT             CON  1          'geiger counter telescope on 1
MinuteLoop      VAR  Nib        'run gct for one minute
GCT00           CON  900        'servo seting for 0 deg
GCT45           CON  1300       'servo setting for 45 deg
GCT90           CON  1900       'servo setting for 90 deg

Workspace       VAR  Word       'temporary storage of data to store in sp ram
experimentLoop  VAR  Byte       'loop control for experiments

adcResult       VAR  Word       'result from adc conversion or other exp
numberOfDigits  VAR  Nib        'number of digits to be stored in nvram

GC_Telescope:

GCT0Deg:
      workSpace = 0
            FOR experimentLoop = 1 TO 30
                  PULSOUT GCT_Servo,GCT00
                  PAUSE 20
            NEXT
            FOR minuteLoop = 1 TO 6             'count for one minute
                  COUNT GM,34843,adcResult
                  workSpace = workSpace + adcResult
            NEXT
            numberOfDigits = 2
            GOSUB Convert_Save_To_SPRAM

GCT45Deg:
      workSpace = 0
            FOR experimentLoop = 1 TO 30
                  PULSOUT GCT_Servo,GCT45
                  PAUSE 20
            NEXT
            FOR minuteLoop = 1 TO 6             'count for one minute
                  COUNT GM,34843,adcResult
                  workSpace = workSpace + adcResult
            NEXT
            numberOfDigits = 2
            GOSUB Convert_Save_To_SPRAM

GCT90Deg:
      workSpace = 0
      FOR experimentLoop = 1 TO 30
            PULSOUT GCT_Servo,GCT90
            PAUSE 20
      NEXT
      FOR minuteLoop = 1 TO 6                   'count for one minute
            COUNT GM,34843,adcResult
            workSpace = workSpace + adcResult
      NEXT
      numberOfDigits = 2
      GOSUB Convert_Save_To_SPRAM
RETURN
```

greater than 3.5 mA at six volts is wasted since it doesn't reduce the resistance across the transistor.

Now, as I understand, the resistance between the 2N3904's emitter and collector isn't really changing as the base current changes. So I don't believe my DMM was really measuring transistor resistance. Also, I don't understand why the resistance measured between the emitter and collector is so different when the DMM leads are switched around (unless the DMM is reverse-biasing the transistor in some way). I suspect that something about how a DMM measures resistance is influencing the transistor's behavior.

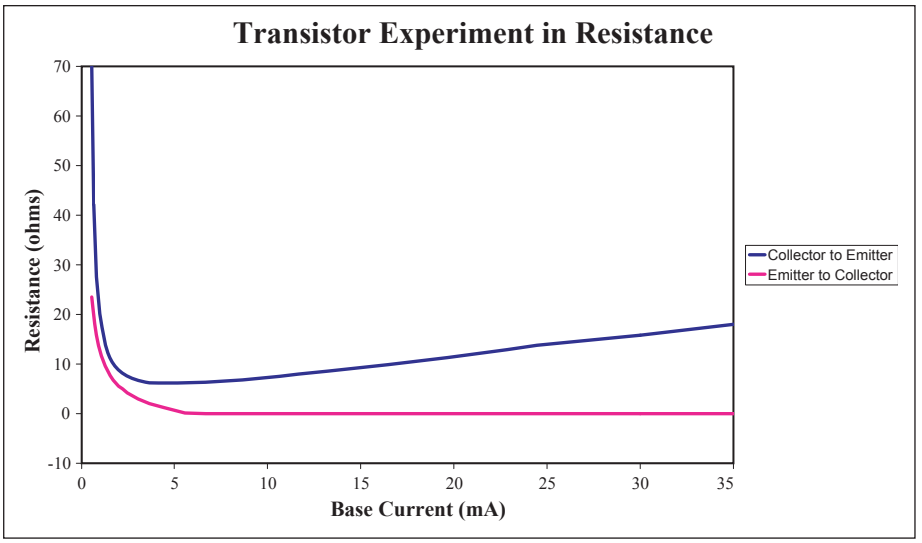


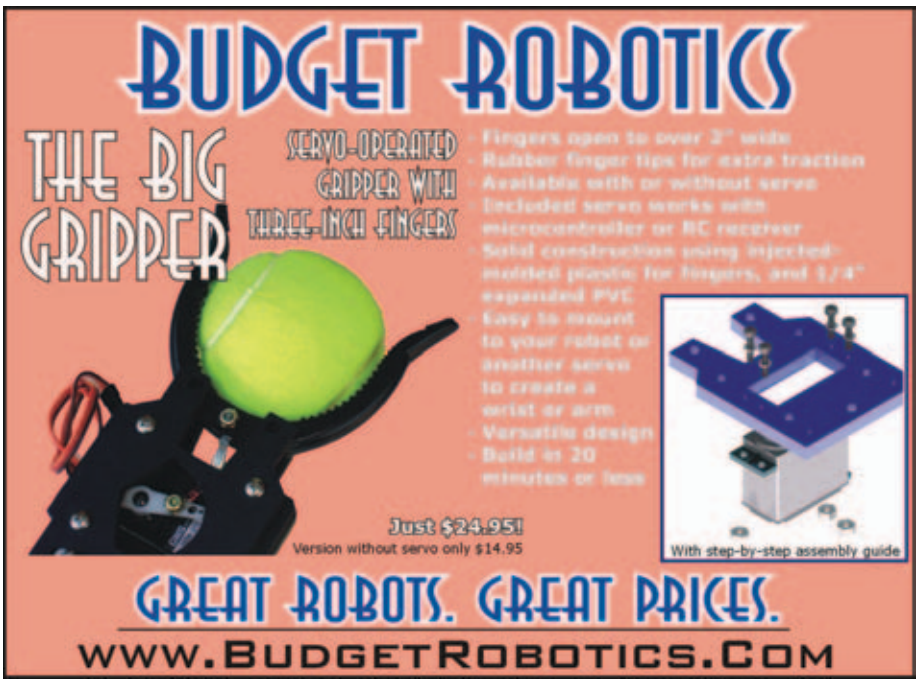
■ FIGURE 5. The transistor schematic.

If you have a good explanation for the experiment's observations, send it to me in an email. If I use your explanation in my next column, I'll send you a patch that's been to near space.

Onwards and Upwards,
Your Near Space Guide **NV**

■ FIGURE 6. You can download a copy of my spreadsheet from the *Nuts & Volts* website; **www.nutsvolts.com**





■ BY PETER BEST

THE EASIEST INTERNET PROTOCOL OF ALL

RS-232-BASED SERIAL PORTS ARE GREAT DATA DONKEYS until you need to move data on an Ethernet LAN or throw it out onto the Internet. Most of the networking email questions I field from *Nuts & Volts'* readers concern moving their data transfers away from traditional RS-232 cables and on to an Ethernet LAN or the Internet. Because of its relative ease of use and implementation, I normally suggest using the UDP protocol. Although it isn't very hard to code up on a microcontroller, TCP/IP is a bit more complicated when compared to UDP as TCP/IP requires more attention from the microcontroller programmer than UDP does.

Unless you create your own custom protocol from scratch, UDP is the closest thing to RS-232 communications you can get in an established Internet protocol. There are no strict timing restrictions associated with UDP. With UDP — as with RS-232 — you can send data at any time you wish. The lack of timing restrictions and the ease of assembling a UDP datagram make UDP the easiest of all of the Internet protocols to implement. This month's Design Cycle will focus on the hardware and firmware you'll need to assemble and deliver UDP datagrams.

WHAT IS UDP?

UDP is short for User Datagram Protocol. It has unofficially been called the Unreliable Delivery Protocol. UDP has absolutely no means of insuring that a data packet will arrive in one piece or even arrive at all. However, you'll find that it is reliable enough to transport small data packets on an Ethernet LAN and the Internet. The data delivery principles behind UDP are very similar to those associated with RS-232. So, if you understand how data is delivered using RS-232, you'll have no problem understanding how UDP does things.

UDP is a very simple protocol. Basically, UDP takes a message (your data) from an application (your microcontroller program) and attaches a checksum and source/destination port numbers before handing over the UDP segment to IP for encapsulation. IP does its best to deliver the UDP segment since there is nothing to guarantee that the UDP segment will arrive intact. In fact, IP is just as unreliable as UDP.

Let's define encapsulation as it is a very important Internet protocol concept. All of you have at one time either received or sent a package of gifts via mail, UPS, or FEDEX. Each gift in the shipment is boxed individually. After marking each individual gift box with the receiver's name, you pack all of the individual gift boxes into a larger shipping carton. The large shipping carton is then addressed and handed over to the delivery person.

When the package arrives at its destination, the shipping carton is opened and discarded. The gift boxes are dispersed to their receivers as marked and the boxes containing the gifts are opened and discarded. The gift is then opened by the recipient and its packaging is also discarded. The process of adding and discarding layers of addressing information to the actual data is called encapsulation.

A UDP host transmits a UDP datagram through a logical source port to a UDP recipient's logical destination port. The destination port number and destination IP address are used to route the UDP segment to the correct application once the segment arrives at its destination. By using port numbers, various applications can be using the services of UDP simultaneously. This is called multiplexing. The combination of the IP address and the port number is called a socket.

Let's examine Hex Dump 1, which is a typical UDP datagram transmission that would flow over an Ethernet LAN. The first six bytes are always the hardware destination address. The

■ NOTE: All code listings and hex dumps are available on the *Nuts & Volts* website at **www.nutsvolts.com**

hardware address is also known as the MAC address. MAC is short for Media Access Control. Every piece of Ethernet LAN hardware must have a unique MAC (hardware) address. This allows you to reuse IP addresses.

For instance, host 192.168.0.100 on LAN A in Fayetteville, TN, can communicate with host 192.168.1.100 on LAN B in Fayetteville, AR, because the Ethernet cards on LAN A and LAN B have unique hardware (MAC) addresses. The applications running on each of the hosts are the only things that care about the IP addresses in this instance.

Once the Ethernet hardware determines (via the MAC address) that it should grab the IP packet, the application sifts through the IP header information to determine where next to route the incoming packet data. Note that the application now has a full return address for the IP part of the packet thanks to the source MAC address and the source IP address. The application also knows that a UDP datagram is encapsulated in the IP data area as the Protocol byte is 17 decimal, which indicates a UDP datagram is the object of this transmission.

The final gate the UDP datagram has to pass through routes the UDP datagram to the correct application port. In the case of Hex Dump 1, the destination port is the well-known echo port. So, the UDP application area that supports echoing incoming characters is summoned to echo the contents of the UDP data area back to the source UDP port via the source IP address by way of the source MAC address. All of which were gleaned from the original incoming IP packet.

As I mentioned earlier, a UDP transmission — such as our echo reply — can occur at any time without the need to establish a structured communications session with the remote host. Since there is no handshaking or predetermined contact between UDP hosts, UDP is defined as a connectionless protocol. This is very similar to the way RS-232 is implemented.

Despite UDP's apparent shortcomings, UDP does have advantages over TCP. For instance, UDP does not have to establish a formal connection and as a result is a faster way to send a message. TCP must use a three-way handshake to establish a communications session before transmitting any data and TCP requires an awful lot of housekeeping compared to none for UDP.

UDP is able to send messages as fast as the microcontroller and application it is involved with can run. The only things that slows UDP down are the limitations of the hardware it is running on and the bandwidth of the LAN it is riding on. Unlike UDP, TCP has built-in rev limiters that throttle the data rate to relieve congestion on the LAN segment. UDP segments with any kind of problems are simply discarded.

BUILDING A UDP DATAGRAM

The layout of the UDP header in Listing 1 and the breakdown in Hex Dump 1 show that the UDP segment rides along as a passenger in the IP data area, which rides inside an Ethernet frame. Thus, the UDP datagram is encapsulated within the IP datagram, as shown in Figure 1. Notice that the UDP source and destination ports are 16 bits in length, which allows port numbers to range from 0 to 65535. Take another look at Hex Dump 1 and you'll see that the UDP header is only eight bytes long, compared to the 20 bytes that make up the IP header. The UDP datagram length or size is simply the total number of bytes in the UDP header plus the number of bytes in the payload or data area.

Using a checksum with UDP is optional. The UDP checksum is put there for use by the application as UDP itself doesn't care about it at all. However, I will show you how to code UDP checksum calculations. The UDP checksum won't make your data's trip any more reliable, but it will help the receiving application determine if what data that did get there is any good.

All you need to do as a network applications programmer is to add your desired IP, UDP, and MAC addresses, compute the IP and UDP checksums, insert your UDP datagram payload, and send the IP packet.

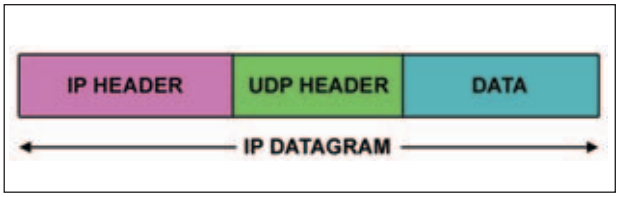
Before we get into building up some AVR hardware to transmit and receive UDP datagrams, let's build up an AVR-based UDP application that runs on an ATmega16.

CODING AN AVR UDP APPLICATION

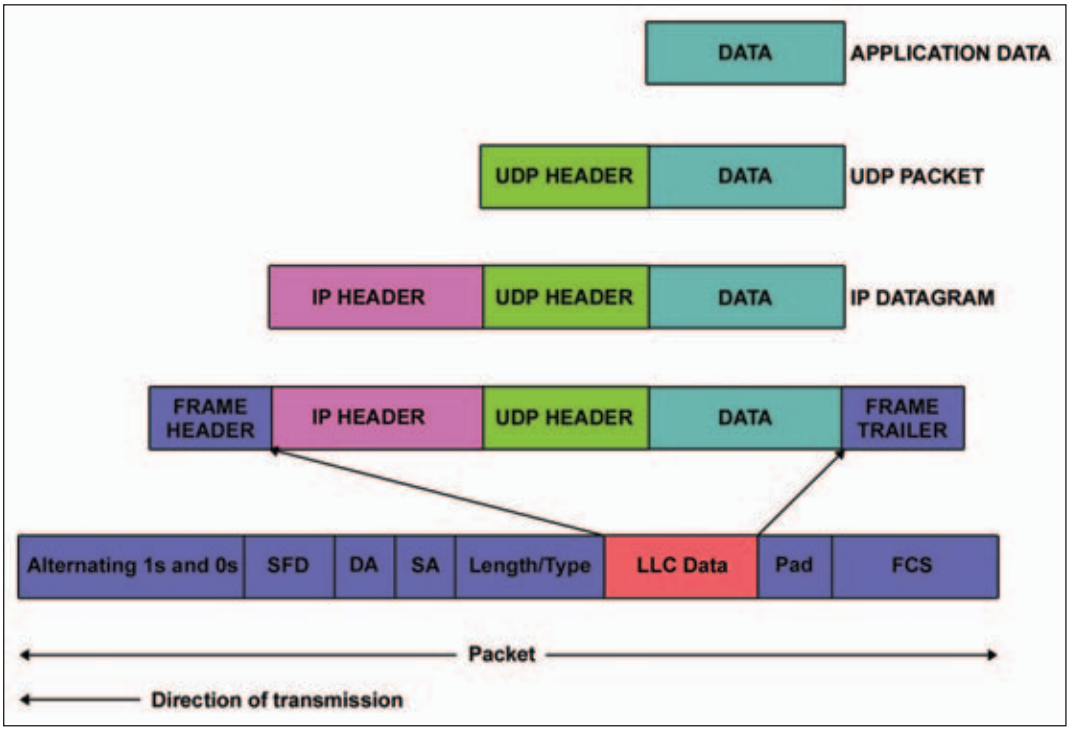
Before anything happens within the UDP application, the microcontroller's networking application has already identified half of the socket — the IP address, which matches the AVR's IP address. The very first thing our UDP application code in Listing 2 does is check the destination port number, which completes the socket address. If the port number is found to be 7, the firmware immediately flows into the process of preparing the frame to be echoed. At this point, we could also check for other UDP port addresses to route the application to other subordinate UDP applications.

Using the addressing information garnered from the incoming IP packet and the local IP and hardware addressing information stored inside the AVR microcontroller, the setipaddrs function shown in Listing 3 points the frame in the microcontroller's packet array memory at the original sender of the frame. In addition to the IP and MAC source and destination address swaps, the UDP source and destination ports must be reversed, as well. All of the IP source/destination turnarounds are performed by the setipaddrs function. The UDP address redirection takes place inside the UDP function shown in Listing 2.

After the addressing in the IP header has been completed, the icing



■ FIGURE 1. There are 28 bytes of header information in the UDP datagram. As you can see in this figure, the UDP datagram is riding inside the IP datagram's data area.



■ FIGURE 2. Here's where we have been working within an Ethernet packet. The only data we have to define consists of the DA (Destination MAC Address), SA (Source MAC Address), Length/Type, and LLC (Logical Link Control) Data. The rest of the packet components are taken care of by the Ethernet engine IC.

to the cake is computing the IP header checksum. The IP header checksum is an inverted summation of the bytes within the IP header plus any summation overflow beyond 0xFFFF. The IP header checksum algorithm is outlined in the Listing 3 cksum function.

When all of the fields within the IP and UDP headers are loaded with the correct data, the UDP checksum calculations in the UDP function outlined in Listing 2 can begin. The UDP checksum calculation process is a bit different than the IP checksum calculation. You would think the UDP checksum would cover only the bytes within the UDP header and data area. However, the UDP checksum includes bytes from the IP header, as well. The UDP checksum is calculated using the following fields:

- The IP source address word
- The IP destination address word
- The IP protocol byte
- The UDP length word
- The UDP header
- The UDP data

The UDP length word is used twice in the calculation of the UDP checksum. Otherwise, the UDP checksum uses the same inverted summation technique as the IP checksum algorithm.

We have assembled a UDP echo reply datagram in the AVR's packet array memory area. I've sliced and diced the IP packet and UDP datagram in Hex Dump 2. With everything now in place, the ATmega16 executes the code contained within the echo_packet function (Listing 4) and sends our UDP datagram along its way.

Figure 2 is an illustration that describes how encapsulation works within the framework of Ethernet, IP, and UDP. The goal behind all of this coding is to allow a network application running within our ATmega16 to send data to another UDP host. In the application I've described, we encapsulated a UDP datagram within an IP packet and sent the data down the line encapsulated within an Ethernet frame.

THE ETHERNET HARDWARE

When it comes to driving an Ethernet host, the Atmel AVR is a very good choice. The ATmega16 has a maximum clock speed of 16 MHz. That may not sound fast when you consider other microcontrollers we've discussed within The Design Cycle run at 40 MHz and 60 MHz clock rates, but the ATmega AVRs execute most instructions in a single cycle and thus are capable of producing up to 16 MIPS with a 16 MHz clock.

The number in the name of an ATmega AVR represents the amount of program Flash in kilobytes. For instance, the ATmega16 contains 16K of program Flash, while an ATmega128 has 128K of program Flash.

SRAM is essential to support the data arrays and variables used within the UDP application. To meet that requirement, the 16K of ATmega16 program memory is supplemented with 1K of SRAM. That's enough to send and receive small UDP packets.

In a networking application, accurate timing routines and delays are just as important as having SRAM buffer space. The ATmega16's trio of eight-bit timers and 16-bit timers allow the creation of precision delays while an on-chip USART (Universal Synchronous Asynchronous Receiver Transmitter) takes care of the housekeeping chores needed to implement a true RS-232 serial port. Twenty-one interrupt vectors cover all of the AVR's networking components including the two-wire interface (Atmel's name for I^2C), the SPI subsystem, and the USART.

I think you can see why I've decided to go with Atmel's ATmega16 as far as this networking project is concerned. The ATmega16's high speed and large program Flash memory areas coupled with ample SRAM make the AVR ATmega16 microcontroller a good choice for small networking devices.

I've applied the ATmega16 in a classic configuration. Schematic 1 shows the ATmega16 supporting an RS-232 port — which is centered around a Sipex SP233ACP — and an RTL8019AS Ethernet engine IC shown in Schematic 2. The ATmega16's 7.3728 MHz clock frequency was chosen to provide minimal baud rate error for the 56Kbps RS-232 port. Provisions have also been made to accommodate in-circuit programming using the inexpensive AVR ISP programming dongle.

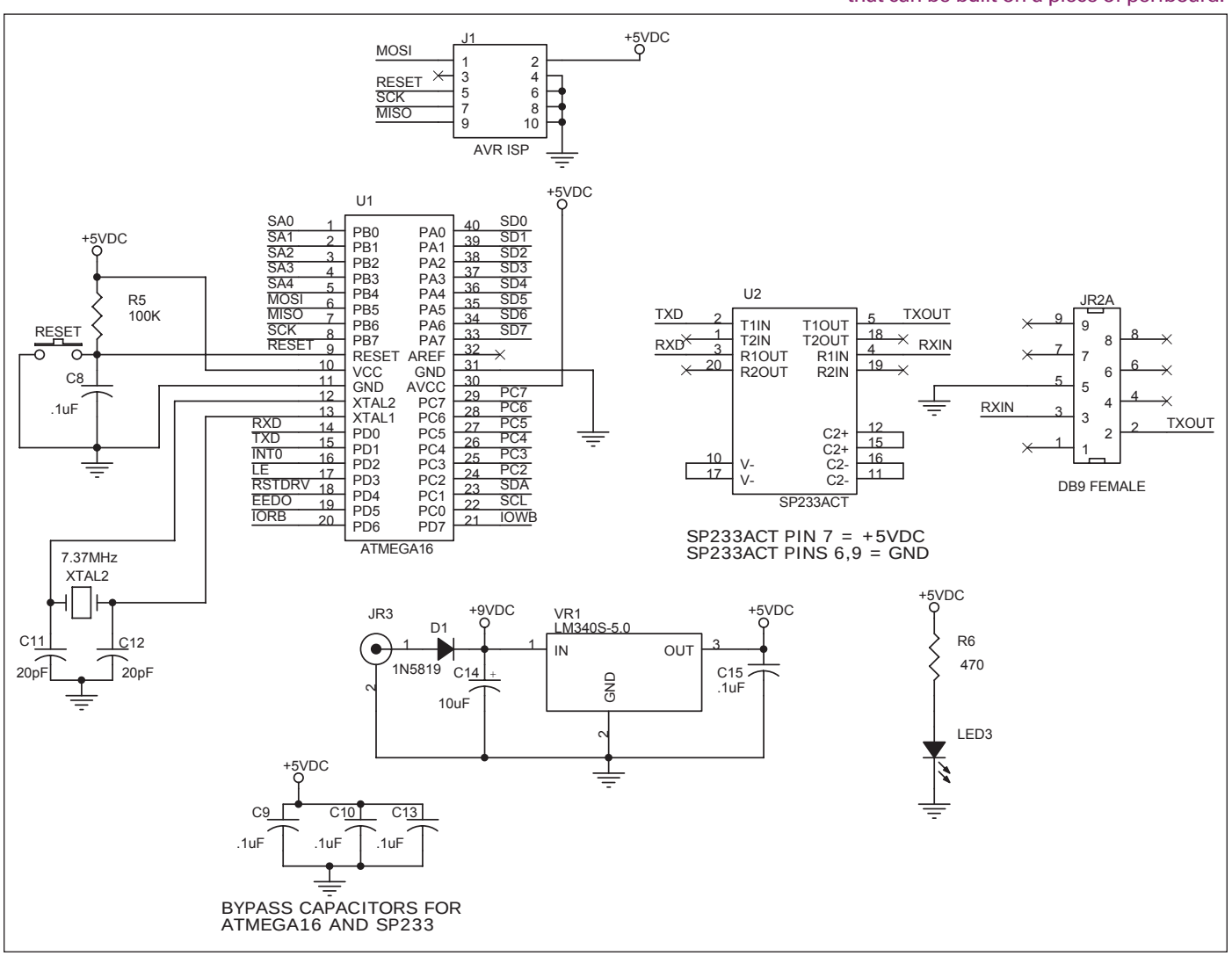
The Realtek RTL8019AS is an NE2000-compatible IC that is easily integrated with just about any microcontroller that has enough I/O to feed the RTL8019AS's address, data, and control lines. Although RTL8019AS is manufactured by Realtek, it is actually based on the National DP8390 Network Interface Controller. The RTL8019AS provides all the Media Access Control layer functions required for transmission and reception of packets in accordance with the IEEE 802.3 CSMA/CD (Carrier Sense Multiple Access/Collision Detection) standard.

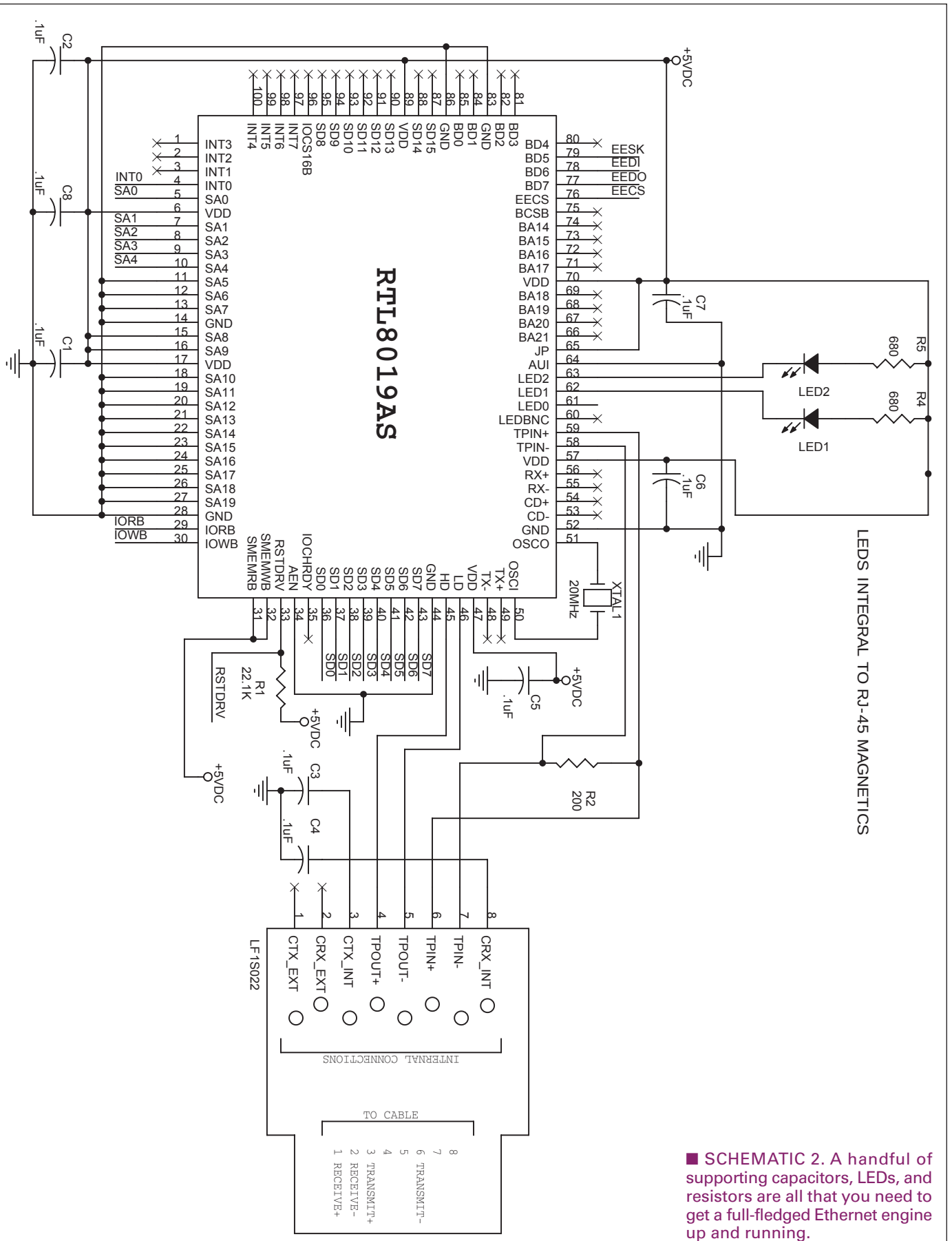
In eight-bit mode, the RTL8019AS uses only 4K of the 16K on-chip SRAM. The use of the full 16K of SRAM within the RTL8019AS can only be accomplished when running in 16-bit mode. In standard NE2000 fashion, the RTL8019AS's 4K of buffer memory is configured as a ring.

The RTL8019AS uses internal DMA resources to manage and move data between the RTL8019AS's FIFO and the Realtek RTL8019AS's internal buffer memory. Within the Realtek RTL8019AS, the onboard FIFO (First In First Out) and Local DMA (Direct Memory Access) channels work in conjunction to form a simple packet management scheme that provides up to 10 megabytes per second internal DMA transfers. The FIFO lies between the network interface and the Local DMA channel.

A second Realtek RTL8019AS Remote DMA channel is included on-chip to get data out of the RTL8019AS's internal Buffer Ring and into and out of the ATmega16's microcontroller memory for processing. It's important to remember that the Local DMA channel moves data between the Realtek RTL8019AS's internal FIFO and the RTL8019AS's Buffer Ring and the Remote RTL8019AS DMA channel moves data between the Realtek RTL8019AS's Buffer Ring and the microcontroller's working memory.

■ SCHEMATIC 1. Nothing new here. Just good old, sturdy microcontroller stuff that can be built on a piece of perfboard.





■ SCHEMATIC 2. A handful of supporting capacitors, LEDs, and resistors are all that you need to get a full-fledged Ethernet engine up and running.

The Realtek RTL8019AS is controlled through an array of on-chip registers. The Realtek RTL8019AS registers are used during initialization, packet transmission, and reception. Using the Realtek RTL8019AS internal registers, we can perform basic operations including defining the hardware physical address, setting the receive parameters, and setting the transmission parameters.

The Realtek RTL8019AS was originally designed for major Ethernet applications in desktop personal computers and some of the RTL8019AS's functionality will be useless to the ATmega16 hardware portrayed in Schematic 1. Not to worry, we won't be writing any code for the "useless" RTL8019AS functionality.

WE'RE NOT DONE YET

UDP is very easy to get up and running on small microcontroller-based systems. Little is needed in addition to the necessary IP header information to pass a UDP message from host to host.

If you still have some blank spaces to fill in your understanding of UDP or the UDP hardware I've just described, fret not. As we continue our discussion of integrating microcontrollers and Internet protocols, I'll revisit and build upon some of the things we've looked at in this installment and introduce you to new concepts as we encounter them in our hardware assembly and Internet protocol coding.

To help you better understand what I have presented in this month's column, I have provided a complete set of C source code for the AVR and RTL8019AS circuitry in this month's Design Cycle as a free download from the *Nuts & Volts* website (**www.nutsvolts.com**). The AVR firmware was originally written using ImageCraft's AVR C compiler. However, you can easily port the C source code for use with the free GNU AVR compiler tools, as well.

The AVR hardware I've offered can support TCP/IP, ICMP, and Telnet applications in addition to the UDP application we discussed. In fact, when you download this month's code package, you'll get all of the drivers for the Internet protocols we have yet to talk about. My goal is to put a mix of microcontrollers and the major Internet protocols into your Design Cycle. **NV**

SOURCES

- *Realtek* — RTL8019AS: **www.realtek.com.tw**
- *ImageCraft* — ImageCraft ICCV7 for AVR: **www.imagecraft.com**
- *Atmel Corporation* — ATmega16: **www.atmel.com**
- WinAVR — C Compiler: **http://sourceforge.net/projects/winavr**

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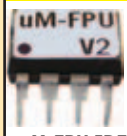

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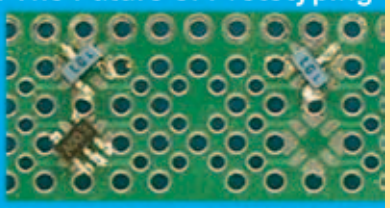
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Continued from page 6

constants, it is about 99.5% fully charged or discharged when being shorted through a resistor. However, with a constant current source, this is a linear instead of a logarithmic phenomenon. As for the predominance of storage scopes being made today, I suggest this critical reader go to the website of the three leading manufacturers — Tektronix, LeCroy, and then Agilent. You will be very hard-pressed to find a single analog oscilloscope still made, so this reader is unfortunately absolutely wrong about this point. Thank you for your interest.

Vaughn Martin

PARTS PREDICAMENT

You have my profound appreciation and thanks for the terrific job you did publishing my article. You guys are the GREATEST! Thanks very, very much. I did get some email from one of your readers in NC who clued me in on a couple of problems with the parts I specified in my parts list:

1. The Sonalert I specified as Digi-Key Part #102-1149-ND will not work as it needs an external driver circuit. A better choice is the CUI Piezo Buzzer w/drive circuit built in, Digi-Key Part #102-1120-ND for $3.27

2. The Push-Button Switch (Normally Closed) I specified as Digi-Key Part #EG2015-ND is actually a Normally Open switch and will NOT WORK AT ALL IN THE CIRCUIT! A better choice is the SPST Momentary NC Switch, Digi-Key Part #450-1103-ND for $5.96. A much less expensive alternative is from RadioShack, #275-1548, Package of 4 for $2.99. My apologies to all the readers.

Chuck Irwin

DISMAY FOR Q&A

I've been a subscriber reading *Nuts & Volts* for about two years now. I enjoy reading your magazine every month. I like the ideas people come up with for projects. The Q&A column usually has some interesting ideas.

However, in the May Q&A column, I was dismayed to find numerous errors. Much of this column was devoted to explaining the basics of MOSFET and IGBT operation and I find it disturbing that this basic information was seriously wrong. As a retired engineer with 40 years of experience — much of it with MOSFET and IGBT circuits — I would like to set the record straight. Hopefully, you will present this corrected information to your readers so they will understand how these devices really work.

MOSFETs — The paragraph on "Miller" capacitance should note that the gate-to-drain capacitance is multiplied by the gain of the MOSFET during the switching time. For instance, using data from the IRF150 data sheet, the gm (forward transconductance) is 9 ohms and if the drain resistor (load resistor) is 3 ohms, the gain is 27 so the effective gate-to-drain capacitance is 27 times the data sheet value.

More importantly, Figure 2 and its description is just plain wrong. First of all, the MOSFET Turn On Characteristics shown should have stated that the gate was driven by a current source (or a voltage source with a large value external gate resistor). Since most real-world circuits do not use current sources to drive the gate, the turn on characteristics will look different in real circuits. Specifically, there will not be a linear rise in gate voltage and there will not be a linear fall in drain current. Also, the regions shown in Figure 2 are wrong! When the gate reaches threshold, Vth, the drain current starts to rise as shown but the drain voltage begins to fall at the same time and the Miller plateau occurs at that point. Furthermore, the Miller plateau is not flat; it gradually rises as the current increases. Lastly, the falling current is incorrectly labeled 'On Resistance.' On Resistance doesn't have any meaning until the drain voltage stops falling (at least most of the way). In region 4 of Figure 2, the On

Resistance does keep falling (not shown), albeit slowly, as the gate voltage keeps rising. Also, the description of section 2 says the drain voltage is typically constant (already commented on) at the source voltage (Vcc). Vcc is not the source voltage; it is the supply voltage.

The next-to-last paragraph should state that reducing the external gate resistor will also speed up the switching time. The statement that the Miller plateau discharge time is governed by the resistance of Rg is confusing. The Miller plateau doesn't get discharged, the gate-to-source capacitance does. The statement should also say the the charge time is governed by the resistance of Rg.

IGBTs — The second paragraph says that the NPN transistor forms a Darlington pair. This could not be more wrong! The NPN transistor is a parasitic device that results from the construction of the IGBT; it is not designed into the IGBT and should never be turned on. The resistor shown in Figure 4 from base to emitter of the NPN transistor is the resistance of metal traces on the IGBT die and is a very low value, usually a few milliohms. If the current through the IGBT is high enough for the voltage across this resistor to turn on the NPN transistor, the IGBT will latch up and cannot be turned off. If some other means cannot turn off this current quickly (in microseconds), the IGBT will be destroyed!!!

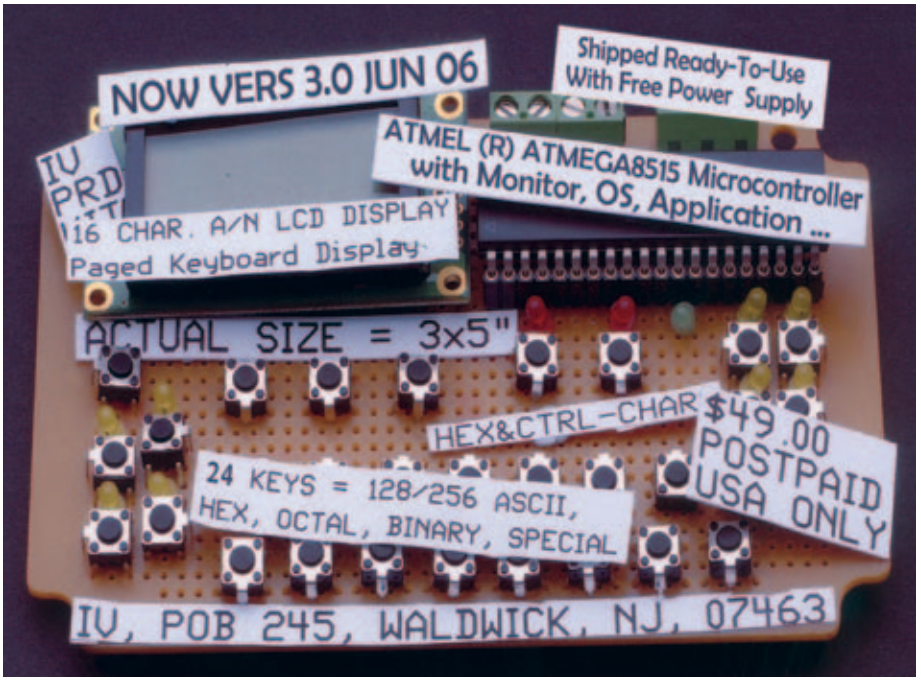
Table 1 (which compares power devices) is misleading as many of these values will vary considerably from device type to device type. It's also wrong about the saturation voltage of the IGBT. IGBT saturation voltage is much higher than most MOSFETs and higher than most bipolar transistors. The MOSFET acts as a resistor in saturation so its voltage drop is simply I times R. If the current is high, you can put many MOSFETs in parallel to get a low voltage drop. The IGBT has the base-emitter junction in series with the resistance of a MOSFET so it has a high voltage drop (usually 1.5 to 3V) even at low currents. Paralleling IGBTs will not have much effect on the voltage drop. So, while some single IGBTs may have a lower drop than some single MOSFETs, parallel MOSFETs will have a lower voltage drop, hence, a lower power dissipation. Figure 5 should say that this assumes either a current source driving the gate or a voltage source with a large gate resistor.

The paragraph that starts "Enter Rs" states the "formula t = 5(RC)." It sounds like you have to wait five time constants for the IGBT to turn on or off. Not true! The time to turn on does depend on the RC product but also depends on the threshold of the particular IGBT and the driving voltage and can be solved using an exponential equation, not a simple one-formula-fits-all equation. Even the exponential equation is not completely accurate because of the non-linearity of the capacitance.

You Take the High Road — Mostly correct except for Figure 10 and its description. The gate driver does not level shift the 15 volts; it only level shifts the signal to its output stage (MOSFET Driver). You must supply a floating 15 volt power supply. If the MOSFET is being continuously switched on and off, a floating 15 volt supply can be made with a diode and capacitor; it's called a bootstrap supply. If the MOSFET will only occasionally be switched on, the gate driver will require a hard supply such as an isolated DC-DC converter or a battery. A battery would work for quite a while as the current drain of the gate driver is very low except when switching the MOSFET. As shown, it does not work!

I can understand not going into too much detail and giving approximations that people can use, but you should try to keep tutorial articles accurate. Giving someone wrong knowledge is worse than giving them no knowledge at all. When giving approximations, say so and say that the detail is beyond the scope of the column.

Stuart Michaels



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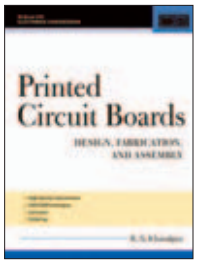

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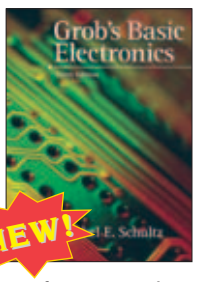

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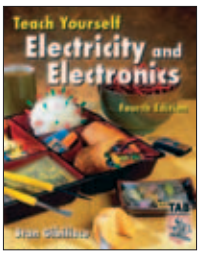

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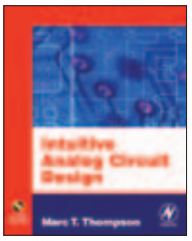
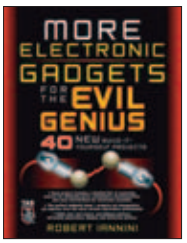


This book introduces analog circuit design with a minimum of mathematics. It gives readers an intuitive "feel" for analog circuit operation and rules-of-thumb for their design. The author uses numerous analogies from digital design to help readers whose main background is in digital make the transition to analog design. The application of some simple rules-of-thumb and design techniques is the first step in developing an intuitive understanding of the behavior of complex electrical systems. This book outlines some ways of thinking about analog circuits and systems that hopefully develops such "circuit intuition" and a "feel" for what a good, working analog circuit design should be. **$59.99**

MORE Electronic Gadgets for the Evil Genius
by Robert E. Iannini



This much anticipated follow-up to the wildly popular cultclassic *Electronic Gadgets for the Evil Genius* gives basement experimenters 40 all-new projects to tinker with. Following the tried-and-true Evil Genius Series format, each project includes a detailed list of materials, sources for parts, schematics, documentation, and lots of clear, well-illustrated instructions for easy assembly. Readers will also get a quick briefing on mathematical theory and a simple explanation of operation along with enjoyable descriptions of key electronics topics. **$24.95**

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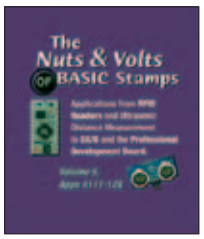
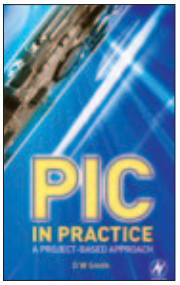
MICROCONTROLLERS

Nuts & Volts of BASIC Stamps — Volume #6
by Jon Williams



Nuts & Volts of BASIC Stamps — Volume 6 includes articles #117-128, written for 2005. Article topics consist of RFID Readers and Ultrasonic Measurement, SX/B and the Professional Development Board, the advanced MIDI receiver, programming the SX microcontroller in BASIC, mastering the MC14489 display driver, and more! The Nuts & Volts of BASIC Stamps books are a favorite Parallax technical pick and are a tremendous technical resource for all PBASIC programming projects. **$14.95**

PIC in Practice
A Project-based Approach
Second Edition
by David W. Smith



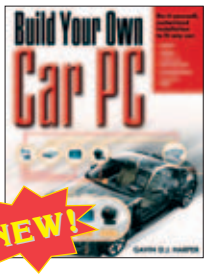
PIC in Practice is a graded course based around the practical use of the PIC microcontroller through project work. Principles are introduced gradually, through hands-on experience, enabling students to develop their understanding at their own pace. The book can be used at a variety of levels and the carefully graded projects make it ideal for colleges, schools, and universities. Newcomers to the PIC will find it a painless introduction, whilst electronics hobbyists will enjoy the practical nature of this first course in microcontrollers. **$29.95**

AUTOMOTIVE

50 Awesome Auto Projects for the Evil Genius
by Gavin D J Harper

The Evil Genius format is the perfect "vehicle" for 50 incredible automotive projects that are compatible with any car, no matter what make, model, or year. Focusing on low-cost, easily obtained components, *50 Awesome Auto Projects for the Evil Genius* lists the items needed to complete each project along with a troubleshooting and repair section. **$24.95**

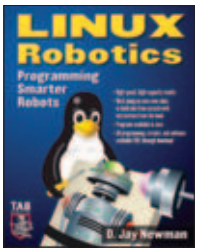
Build Your Own Car PC
by Gavin D J Harper



This is a heavily-illustrated, step-by-step guide to installing and controlling a car PC — using commonly-available, off-the-shelf components. Numerous how-to photos and product shots allow you to easily navigate each step even if you have little "do-it-yourself" experience. Includes parts and required tool lists, troubleshooting tips, and a list of manufacturers where you can purchase the parts best suited for your customized system. **$27.95**

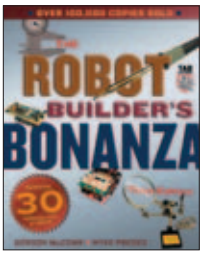
ROBOTICS

Linux Robotics
by D. Jay Newman



If you want your robot to have more brains than microcontrollers can deliver — if you want a truly intelligent, high-capability robot — everything you need is right here. *Linux Robotics* gives you step-by-step directions for "Zeppo," a super-smart, single-board-powered robot that can be built by any hobbyist. You also get complete instructions for incorporating Linux single boards into your own unique robotic designs. No programming experience is required. This book includes access to all the downloadable programs you need, plus complete training in doing original programming. **$34.95**

Robot Builder's Bonanza
Third Edition
by Gordon McComb/Myke Predko



Everybody's favorite amateur robotics book is bolder and better than ever — and now features the field's "grand master" Myke Predko as the new author! Author duo McComb and Predko bring their expertise to this fully-illustrated robotics "bible" to enhance the already incomparable content on how to build — and have a universe of fun — with robots. Projects vary in complexity so everyone from novices to advanced hobbyists will find something of interest. Among the many editions, this book features 30 completely new projects! **$27.95**

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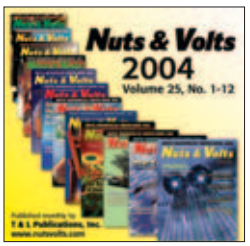
Build & Upgrade Your Own PC — Fourth Edition
by Ian Sinclair

Ian Sinclair's "Build Your Own" books have established themselves as authoritative and highly practical guides for home and small business PC users and IT technicians alike. *Build & Upgrade Your Own PC — Fourth Edition* is based around building and upgrading to the latest systems, such as Pentium 4 or AMD Athlon XP motherboards running Windows XP and Windows 2000 Professional. As well as guiding you around the inside of your PC base unit, Ian Sinclair also covers setup, and security issues and peripherals. **$34.95**

Nuts & Volts CD-Rom



Here's some good news for *Nuts & Volts* readers! Starting with the January 2004 issue of *Nuts & Volts*, all of the issues through the 2004 calendar year are now available on a CD that can be searched, printed, and easily stored. This CD includes all of Volume 25, issues 1-12, for a total of 12 issues. The CD-Rom is PC and Mac compatible. It requires Adobe Acrobat Reader version 6 or above. Adobe Acrobat Reader version 7 is included on the disc. **$29.95**

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TECH FORUM

This is a READER-TO-READER Column.

All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

All questions and answers should be sent by email to forum@nutsvolts.com All *diagrams should be computer generated and sent with your submission as an attachment.*

QUESTIONS

To be considered, all questions should relate to one or more of the following:

❶ Circuit Design
❷ Electronic Theory
❸ Problem Solving
❹ Other Similar Topics

■ Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).
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■ Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

>>> QUESTIONS

I want to build a light timer/controller for a reef aquarium that would incrementally turn on a bank of fluorescent lights and/or metal halide lights in a specific order in the morning, then off in the opposite order in the evening. This would simulate the rise and fall of the sun. I need some manual control of the on/off process. I could use an array of individual timers from the hardware store, but that takes more room and outlets than I like. Can something a little more compact and versatile be done with 555s or similar circuits? I don't want to use microcontrollers because of the extra complexity, programming, etc. Any help is greatly appreciated.

#7061 Phil Daniels
Novice Reef Aquarium Owner
Striving To Be An Advanced Reef Aquarium Owner

I have a mini DV camcorder which came with a Lithium-ion 800 mA 7.4V power pack. It lasts about an hour in camera mode. There is a battery indicator on the LCD screen with five dots to denote the capacity (five dots for 100% and three dots for 60% etc.) The indicator starts to blink when the battery drops below 20%.

I replaced the battery pack with a fully charged 6AA Ni-MH (1,800 mA 1.2V x 6). Immediately the indicator started to blink. The battery lasts only 30 minutes. (A 1,000 mA ampere meter was connected and it showed the camera drew only 700 mA/h Can anyone shed some light on this?

#7062 Robert Treuer
Ontario

For several years now, I have been experimenting with a wireless intercom system that uses the ground for its medium. I have desired to transmit and receive voice frequencies only, since I believe that 300 to 3,000 Hz is an unregulated part of the spectrum. I have had excellent success building receivers (which are really nothing more than glorified filtered audio amps with the inputs tied to two poles stuck in the ground), but I'm having trouble getting my transmitters to go farther than a few hundred yards. My latest transmitter delivers 170V peak-to-peak swing straight to a copper pipe driven about eight feet in the ground and still won't carry even half a mile. Heinrich Barkhausen in WW2 spied on allied army field phones by hooking a sensitive audio amplifier to two poles driven in the ground. He picked up eddy currents from conversations miles away and was able to

understand them. If he could pick up signals unintentionally induced into the ground, then why can't I find the secret to sending intentional currents into the ground to my cousin's house about two miles away? My goal is to have a two-way intercom between his house and mine. I know it can be done. I once read a radio electronics book at the local library where the author and a friend plugged their guitar amps into the ground, in a similar way, and could pick each other up at about two miles. Ideas?

#7063 **J.B.Young**
Gravel Switch, KY

I purchased a GOLDSTAR DC power supply model GP-305. There are some LEDs, switches, and terminals that I have not been able to figure out. Can anyone tell me the function of these or have a manual I might be able to copy?

The mystery elements are:

1. A switch marked EXT/INT.
2. An LED marked C.C.
3. An LED marked C.V.
4. A external terminal strip with the following contacts /C1/C2/+/EXT/-/PL/GND.

I have figured out GND.

#7064 **Robert B. Lang Jr**
via email

I quite enjoyed reading Russell Kincaid's response on a simple current sensing circuit. Another tougher problem is on measuring the 250V plus DC voltage. Can Russell or anyone else suggest a circuit that is isolated from the microcontroller?

#7065 **Steve Yang**
Sunnyvale, CA

I bought a TL507C — a one bit AD converter chip in the mid 80s. It's been sitting idle since then and I've been thinking of using it with my Timex 1000 computer, to measure temperature, if possible.

What are some practical applications that a one bit converter chip could be used for?

#7066 **Theodore Turk**
Euclid, OH

>>>> ANSWERS

[#6063 - June 2006]

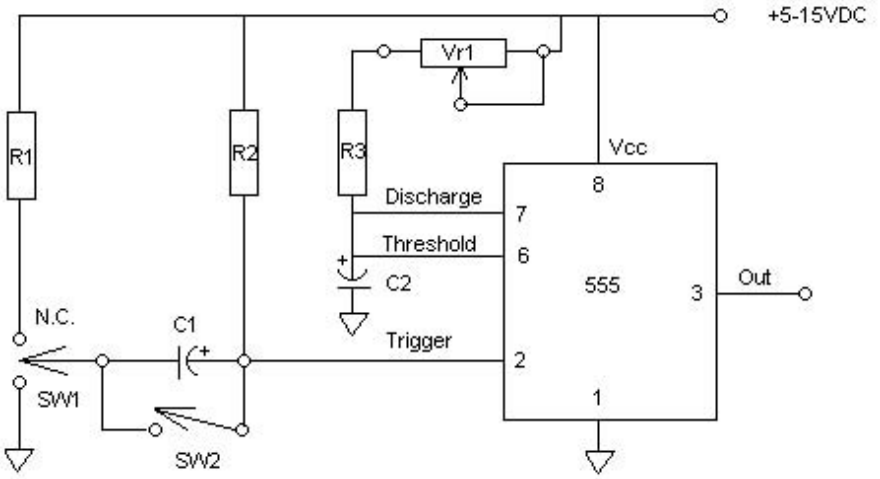
I have a spot welder that I want to use on delicate metal. The trigger is not reliable due to its unpredictable "on" time. Is there a way to build a timer that would regulate the "on" time to very short but accurately repeatable (one shot) bursts?

#1 Here is a schematic of a 555 chip configured as a one shot timer. The schematic also includes switch one, used to activate the timer, and switch two, to change back to manual control. This is just a matter of convenience so you can use switch one in timed or manual configuration. When switch two is open, it's a one shot device. When switch two is closed, switch one acts "normal." Press for on. Release for off.

Switch one is normally closed to R1 (10K) so the wiper is high. When you press switch one, C1 discharges to ground and a pulse pulls the trigger input low. R2 and C1 set the amount of time the trigger line can stay low. The trigger must go high before the one shot times out because the timer will not stop until the trigger line goes high. For C1 = 10 µF and R2 = 10K, switch one holds the trigger line low for 55 milliseconds (T = .55RC). Using the same values for C2 and R3 sets a minimum on time of 110 milliseconds. (T = 1.1 RC). A 100K linear pot (Vr1) allows adjustment up to 1.2 seconds of on time. If you have trouble with double firing, you can double or triple the values of all three fixed resistors. That should slow everything down enough to ignore switch bounce, but the minimum on time will also double or triple.

The output is defined as "on equals high." You did not say anything about what kind of signal is being switched to activate the welder, so you will have to design the appropriate circuit to convert "high at pin 3" to whatever it is that needs to be switched to make the welder activate.

C.L. Larson
Largo, FL



#2 Here's basically what you will need to control the welder. I have just begun designing a circuit to remedy this exact problem; so here's my approach.

A spot welder needs to have its weld time very precisely controlled, in terms of power line cycles. I plan to use a microcontroller such as the 8051 or similar as the core, since I already have a basic development setup for that. You can use any controller that has the needed I/O pins.

For the peripheral circuitry, it will need a zero-cross detector for power line timing. This will feed an input bit on one of the ports; most likely I will use one of the interrupt pins for that function. It will also need an input pin that detects when the trigger on the welder has been tripped. If your welder is like those from one of the mail-order tool stores (e.g., Harbor Freight), the trigger switch will have to

be rewired to isolate it from the power line, and brought back into the controller.

Next, it will need a keypad to input the weld parameters. A 3x4 matrix keypad similar to a touch tone phone keypad should work nicely. Of course, it will need a display to prompt for user input and to tell the user what's happening. One of the cheap one or two line LCD displays should fit the bill.

Next, it will need an output pin to drive a large optically isolated triac, which, of course, turns the power to the welder on and off.

The key to all this is the software that will run in the microcontroller. I have some basic ideas for the software, but as yet, I haven't written any code. Basically, it will need to have the following functions:

1) Ask the user for the weld time in either number of power cycles or in seconds.

2) Wait for the trigger to be pulled.

3) Turn the triac on for the specified time or number of power cycles.

4) Turn the triac off.

It should have a time delay built in to enforce the duty cycle rating of the welder so you don't burn up the welder.

A word of caution is necessary, because lethal voltage is used by the welder. If you don't know and understand the precautions that you should use, then please don't attempt a project like this.

I don't have a lot of time to work on this, but it is destined to be a summer project for me. I'll be glad to pass on any discoveries as I discover them.

Weld On!!!!

David Mason
Middleburg, FL

[#6062 - June 2006]

I have two JumpDrives and was wondering if there is a chip to make it work like a USB JumpDrive MP3 player. I see that they sell them, but I want to build one. Does anyone have a schematic or any ideas?

Here are several web links to home-built MP3 players.

www.frankvh.com/mp3player/
web.media.mit.edu/~ladyada/make/minty/
www.teuthis.com/html/mp3.html

Here are some links to MP3 codecs and USB interface ICs:

Atmel – AT43USB370 USB 2.0 Full-Speed Host/Function Processor - **www.atmel.com/dyn/products/product_card.asp?part_id=3393**

STMicro – STA013 MPEG 2.5 LAYER III (MP3) AUDIO DECODER - **www.st.com/stonline/products/literature/ds/6399.pdf**

Daryl Rictor
via the Internet

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Also Available w/Digital Display & MicroProcessor Controller

Item# CSI-STATION2A

$49.95

Details at Web Site

SMD Hot Tweezer Adaptor Fits CSI Stations 1A & 2A and CSI906

$29.00

Item# CSITWZ-STATION

> Soldering Equipment & Supplies > Soldering Stations

In Business

Circuit Specialists Inc.

Since 1971

Programmable DC Electronic Loads

The CSI 3700 series electronic loads are single input programmable DC electronic loads that provide a convenient way to test batteries and DC power supplies. It offers constant current mode, constant resistance mode and constant power mode. The backlight LCD, numerical keypad and rotary knob make it much easier to use. Up to 10 steps of program can be stored.

Model	CSI3710A	CSI3711A
Input Voltage	0-360V DC	0-360V DC
Input Current	0-30A DC	0-30A DC
Input Power	0-150W	0-300W

CSI3710A: $349.00 **CSI3711A: $499.00**

50,000 Count Advanced DMM w/RS232

- DC voltage: 1000V
- AC voltage: 750V
- DC accuracy 0.05%
- Low voltage Ohms measurement and conductance
- Auto and software calibration
- Dual back-lit display and K type thermocouple
- Measures duty cycle, pulse width and conductance
- Compare function for go-no go testing
- Peak detection for capturing high speed signals
- Binary bit expression bar graph
- AC and AC + DC true RMS AC voltage and current measurements
- Auto/manual ranging
- Test zener diodes up to 20 volts
- Min/Max/Avg relative modes
- Memory store and recall
- Fuse protected current ranges
- Cat II 600V and CE approved

Protek

MSRP $199.00

Item# PROTEK608

$129.00

New Lower Price!

Details at Web Site

> Test Equipment > Digital Multimeters

Heavy Duty Regulated Linear Bench Power Supplies

- Multi-loop high precision voltage regulation
- Automatic voltage & current stabilizing conversion
- Automatic radiant cooling system
- Over-heating protection

CSI5030S: 0-50v/0-30amp **$595.00**

CSI12005S: 0-120v/0-5amp **$595.00**

CSI20002S: 0-200v/0-2amp **$595.00**

Details at Web Site

> Test Equipment > Power Supplies

Dual Output DC Bench Power Supplies

As Low As **$93.00!**

High stability digital read-out bench power supplies featuring constant voltage and current outputs. Short-circuit and current limiting protection is provided. SMT PC boards and a built-in cooling fan help ensure reliable performance and long life.

- Source Effect: $5x10^{-4}$=2mV
- Load Effect: $5x10^{-4}$=2mV
- Ripple Coefficient:: <250uV
- Stepped Current: 30mA +/- 1mA

HOT ITEM!

*All 3 Models have a **1A/5VDC Fixed Output** on the rear panel*

CSI3003X-5: 0-30v/0-3amp 1-4: **$97.00** 5+: **$93.00**

CSI5003X5: 0-50v/0-3amp 1-4: **$107.00** 5+: **$103.00**

CSI3005X5: 0-30v/0-5amp 1-4: **$119.00** 5+: **$115.00**

Details at Web Site > Test Equipment > Power Supplies

Triple Output Bench Power Supplies

with Large LCD Displays

- Output: 0-30VDC x 2 @ 3 or 5 Amps & 1ea. fixed output @ 5VDC@3A
- Source Effect: $5x10^{-4}$=2mV
- Load Effect: $5x10^{-4}$=2mV
- Ripple Coefficient: <250uV
- Stepped Current: 30mA +/- 1mA
- Input Voltage: 110VAC

CSI3003X3: 0-30VDCx2 @3A **$179.00** 5+: **$169.00**

CSI3005XIII: 0-30VDCx2 @5A **$219.00** 5+: **$209.00**

Details at Web Site > Test Equipment > Power Supplies

Circuit Specialists, Inc. 220 S. Country Club Dr., Mesa, AZ 85210
800-528-1417 / 480-464-2485 / FAX: 480-464-5824

ESD Safe CPU Controlled SMD Hot Air Rework Station

The heater and air control system are built-in and adjusted by the simple touch of the front keypad for precise settings. Temperature range is from 100°C to 480°C / 212°F to 896°F, and the entire unit will enter a temperature drop state after 15 minutes of non-use for safety and to eliminate excessive wear.

Item# CSI825A++ Only $199.00!

- •CPU Controlled
- •Built-in Vacuum System
- •Temperature Range:100°C to 480°C / 212°F to 896°F
- •15-Minute Stand-By temperature "sleep" mode
- •Power:110/120 VAC, 320 W maximum

Details at Web Site > Soldering Equipment & Supplies

Protek 2.9GHz RF Field Strength Analyzer

The 3290 is a high quality hand-held RF Field Strength Analyzer with wide band reception ranging from 100kHz to 2900MHz.The 3290 is a compact & lightweight portable analyzer & is a must for RF Technicians. Ideal for testing, installing & maintenance of Mobile Telephone Comm systems, Cellular Phones,Cordless phones, paging systems, cable & Satellite TV as well as antenna installations.May also be used to locate hidden cameras using RF transmissions.

Item# 3290

Fantastic Low Price: $1899.00!

- •WFM/NFM/AM/SSB modulated signals may be measured.
- •Signal Levels up to 160Channels can be displayed simulaneously on the LCD
- •PLL tuning system for precise frequency measurement and tuning
- •Built-in Frequency Counter
- •LED Backlight LCD (192x192 dots)
- •All fuctions are menu selected.
- •RS232C with software for PC & printer interface
- •Built-in speaker

(Includes Antenna)

Details at Web Site > Test Equipment > RF Test Equipment

Breadboard / Power Supply / MultiFunction DMM Bundle

Provides the user with a quick and efficient system for breadboarding electronic circuits. Comes with three built-in regulated power supplies along with a deluxe, easy-to-use breadboard. Included is a multifunction DMM with 100VDC, 750VAC, frequency, resistance, diode test, audible continuity, transistor check,temperature, and capacitance.

A Super Deal!

Details at Web Site > Breadboards & Prototyping Boards

Powered Breadboard w/out DMM: $69.00

Only $69.99!

Item#: PBB-272DMM BUNDLE: $69.99!

Powered Breadboard w/Multifunction DMM (CSIMS8264)

You Get The DMM for an Extra $.99

Butane Portable Soldering Iron & Kit

- •Electronic Instant Ignition System
- •Naked Flame Burner: Temp to 1300°C/2370°F
- •Flameless Burner: up to 400°C/750°F

Two-Piece Iron comes with Solder Tip.

RK3212: Solder Iron $14.95

- •Equipped with U.S.CPSC Approval Child Safety Standard
- •Electronic Instant Ignition System
- •Naked Flame Welding: Temp to 1300°C/2370°F
- •Soldering Temp: up to 500°C/930°F
- •Heat Shrinking: up to 500°C/930°F
- •Hot cutting of plastic sheets or plates

RK3124: Solder Kit $34.00

Details at Web Site > Soldering Equipment & Supplies > Soldering Irons

Digital Storage Oscilloscope Module

PC based Digital Storage Oscilloscope, 200MHz 5GS/s equiv. sampling USB interface

Convert any PC with USB interface to a high performance Digital Storage Oscilloscope. This is a sophisticated PC basedscope adaptor providing performance compatible to mid/high level stand alone products costing much more! Comes with two probes.

Details & Software Download at Web Site

Price Breakthrough!

> Test Equipment > Oscilloscopes/Outstanding Prices

Item# 200DSO Only $749.00

Protek 20MHz Dual Trace Oscilloscope

- •20MHz Bandwidth
- •Alt-Mag sweep for simultaneous display of main and X5 magnified trace
- •1mV/Div Vertical sensitivity
- •Alternate trigger for a stable display of unrelated signals
- •Multi-level trigger
- •X5 Sweep Magnification

Item# PROTEK 6502

$279.00!

Details at Web Site

> Test Equipment > Oscilloscopes/Outstanding prices

Protek 2MHz Sweep Function Generator

- •0.02Hz-2MHz(7 Ranges)
- •Sine,Triangle,Square,Pulse,Ramp, Slewed Sine Waveform
- •Sync. Out (TTL Square Waveform)
- •Accuracy: ±5% of Full Scale to 200KHz, ±8% of Full Scale from 200KHz-2MHz
- •Sweep Function
- •VCG Input

Item# PROTEK 9205

Special $139.00! Any Quantity

Details at Web Site

> Test Equipment > Function Generators

SONY Super HAD CCD Color Weatherproof IR Cameras

480 TV Lines Resolution

- •Day & Night Auto Switch
- •Signal System: NTSC
- •Image Sensor: 1/3" **SONY Super HAD CCD**
- •Horizontal Resolution: 480TV lines
- •Min. Illumination: 0Lux

Item# VC-827D: $132.00

SONY Super HAD CCD™ equipped camera's feature dramatically improved light sensitivity

Intelligent DMM w/ RS-232

- •3999 Counts and 38 Segment Bar Graph
- •Dual Display (digits & bar graph)
- •Capacitance Function, Transistor & Diode Test
- •Frequency Range & Temperature
- •RS232C Standard Interface
- •Data Hold

Item# CSI345

SALE $29.95

Details at Web Site

> Test Equipment > Digital Multimeters/World Beater Prices

SONY Super HAD CCD B/W Weatherproof IR Camera

- •Day & Night Auto Switch
- •Signal System: EIA
- •Image Sensor: 1/3" **SONY Super HAD CCD**
- •Horizontal Resolution: 420TV lines
- •Min. Illumination: 0Lux

Item# VC-317D: $59.50

Details at Web Site

SONY Super HAD CCD Color Camera

- •Weather Proof
- •Signal System: NTSC
- •Image Sensor: 1/4" SONY Super HAD CCD
- •Horizontal Resolution: 420TV lines
- •Min. Illumination: 1Lux/F1.2

Item# VC-805: $53.95

> Miniature Cameras(Board,Bullet,Mini's, B/W, Color)

SONY Super HAD CCD Color Weatherproof IR Camera

- •Day & Night Auto Switch
- •Signal System: NTSC
- •Image Sensor: 1/4" **SONY Super HAD CCD**
- •Horizontal Resolution: 420TV lines
- •Min. Illumination: 0Lux

Item# VC-819D: $62.50

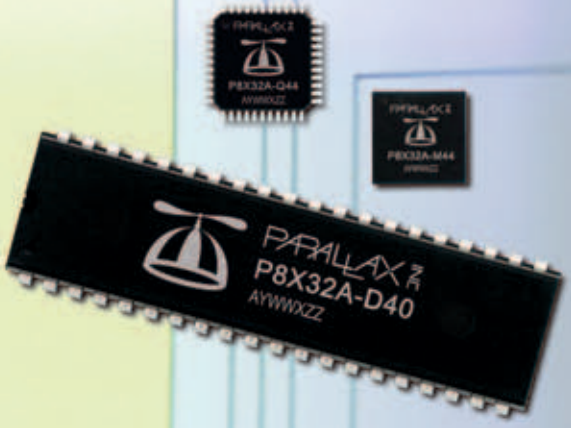
Visit our website for a complete listing of our offers. We have over 8,000 electronic items on line @ **www.CircuitSpecialists.com**. PC based data acquisition, industrial computers, loads of test equipment, optics, I.C's, transistors, diodes, resistors, potentiometers, motion control products, capacitors,miniature observation cameras, panel meters, chemicals for electronics, do it yourself printed circuit supplies for PCB fabrication, educational D.I.Y. kits, cooling fans, heat shrink, cable ties & other wire handleing items, hand tools for electronics, breadboards, trainers, programmers & much much more! ***Some Deals you won't believe!***

Propeller™

Chip by Parallax, Inc.

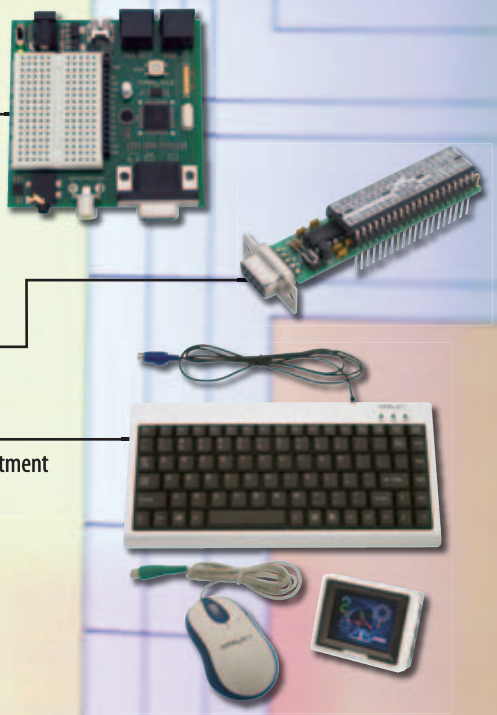
What can you do with eight 32-bit processors (COGs) in one chip? Real simultaneous multi-processing! The new Propeller chip is the result of our internal design team working for eight years. The Propeller chip was designed at the transistor level by schematic using our own tools to prototype the product. The Propeller is programmed in both a high-level language, called Spin™, and low-level (assembly) language. With the set of pre-built Parallax "objects" for video, mice, keyboards, RF, LCDs, stepper motors and sensors your Propeller application is a matter of high-level integration. Propeller represents the first custom all-silicon product designed by Parallax. *The Propeller is recommended for those with previous microcontroller experience.*

Propeller Chip Specifications	
Power Requirements	*3.3 volts DC*
External Clock Speed	*DC to 80 MHz (4 MHz to 8 MHz with Clock PLL running)*
Internal RC Oscillator	*12 MHz or 20 KHz*
System Clock Speed	*DC to 80 MHz*
Global RAM/ROM	*64 K bytes; 32K RAM / 32 K ROM*
Processor RAM	*2 K bytes each (512 longs)*
RAM/ROM Organization	*32 bits (4 bytes or 1 long)*
I/O Pins	*32*
Current Source/Sink per I/O	*50 mA*



Propeller users have already been hard at work developing Objects for the Propeller Object Library and discussing Propeller programming on our online forums. To join in visit www.parallax.com/propeller.

Propeller Chips	Stock Code	Price
P8X32A-D40 (40-Pin DIP) Chip	#P8X32A-D40	$25.00
P8X32A-Q44 (44-Pin QFP) Chip	#P8X32A-Q44	$25.00
P8X32A-M44 (44-Pin QFN) Chip	#P8X32A-M44	$25.00
Propeller Tools	**Stock Code**	**Price**
Propeller Demo Board	#32100	$129.95
PropSTICK Kit	#32310	$79.95
Propeller Accessories Kit	#32311	$99.00



To order online visit www.parallax.com/propeller. To order by telephone call the Parallax Sales Department toll-free at 888-512-1024 (Monday-Friday, 7 a.m. to 5 p.m., Pacific Time).

PARALLAX

www.parallax.com